OFFICE OF NAVAL INTELLIGENCE,

GENERAL INFORMATION SERIES, NO. VIII

INFORMATION FROM ABROAD.

64254

NAVAL MOBILIZATION

AND

IMPROVEMENT IN MATÉRIEL.

JUNE, 1889.

NAVY DEPARTMENT,
BUREAU OF NAVIGATION,
OFFICE OF NAVAL INTELLIGENCE,
1889.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1889.

TABLE OF CONTENTS.

	Page.
Introductory note	v
I. Naval mobilization	1
II. The naval manœuvres of 1888	23
III. Distribution of armor	81
IV. The development of the high-power gun	135
V. Naval gunnery	163
VI. Fish-torpedo armament	185
VII. Propulsion	199
VIII. Electricity for naval purposes	245
IX. The development of the resources of the United States for the production of war material	293
Notes on ships, machinery, ordnance, armor, torpedoes, torpedo-boats, and other subjects of professional interest	327
Ships	329
Machinery	362
Ordnance	375
Armor	424
Torpedoes	428
Torpedo-boats	437
The manœuvering power of ocean steamers	456
Index	465

INTRODUCTORY.

The annual publication of the Office of Naval Intelligence for 1889, General Information Series, No. VIII, presents, first, a statement of the various plans for naval mobilization existing in England, France, Italy, and Germany, followed by an account of the principal naval manœuvres of 1888, conducted largely with a view of testing the machinery for mobilization; second, a discussion of the improvement and employment of different weapons, machines, and apparatus in naval or marine use, and a review of the improved resources of the United States for producing war material; and, third, the customary Notes upon the naval progress of the year.

Chapter I describes the systems existing in England, France, Germany, and Italy for rapid naval mobilization. In these, as in all European countries, the greatest attention is being devoted to perfecting preparations for rapidly passing from a peace to a war footing.

Chapter II describes the English, French, Italian, and Spanish manœuvres of 1888. These varied somewhat in character. Those of the English were intended to test the resources of the dock-yards for rapidly mobilizing a large fleet, to determine the practicability of effectively blockading an enemy's fleet in his home ports, to determine the efficiency of vessels of new types, and to illustrate the defenseless condition of the British coasts and food supply. The French manœuvres were altogether devoted to testing the resources of the Toulon arsenal for the mobilization of a large squadron of armor-clads; while the Italians chose for their theme the attack and defense of Spezia, descents upon the Italian coast, and the destruction of littoral railways. The Spanish manœuvres were restricted to the determination of the value of the torpedo-boat flotilla.

The landing and subsequent operations of the naval brigade of the North Atlantic squadr re also described.

Chapter III prese graphic review of the changes which have taken place in nav n concerning the distribution of armor on war ships; togeth extracts from a paper read before the Institution of Naval cts, in England, by the Director of Naval Construction of t ralty, descriptive of the design for eight new armor-clads which England is to complete by 1894, and from other papers recently published by Sir Nathaniel Barnaby, in England, and Admiral Albini, in Italy, containing novel and noteworthy views.

Chapter IV reviews the advances made in the development of the high-power gun, its mounts, ammunition, and equipment.

Chapter V, contributed by Lieut. J. F. Meigs, U. S. Navy, recently the gunnery officer of the North Atlantic squadron, invites earnest attention to more careful instruction and training in the art of naval gunnery. The subject is treated under the heads of Marksmanship, Control, and Tactics, and presents information valuable to all officers, whether serving afloat or engaged in the determination of designs for war ships.

Chapter VI presents information concerning the installation of the fish-torpedo armament of vessels in the principal navies of Europe. The appearance of several books recently offered abroad for public sale has rendered practicable the publication of the contents of this chapter.

Chapter VII presents a résumé of the opinions of distinguished writers upon the question of marine propulsion, and of experiments made by them to determine the efficiency of propellers of various characters.

Chapter VIII has been prepared through the courtesy of the Naval Inspector of Electric Lighting, Navy Department, by his assistants. It contains much relating to electrical plants that will be valuable to naval officers charged with their care and management in our new ships and to electricians at large.

Chapter IX reviews briefly the development of the resources of the United States for the production of war material. Absolutely dependent in 1886 upon European manufacturers for the supply of heavy gun-forgings, armor-plates, steel shafting, rapid-fire guns, and torpedoes, the country, in 1889, finds within its territory the plant ready for producing every component part of the modern war ship. That this is a subject for congratulation is evident; that the result is due to the persistent effort of the Navy Department and navy officers, assisted in Congress by a few ardent advocates of increasing our resources for the national defense, will, it is believed, be recognized after an examination of this chapter.

The number concludes with the yearly Notes descriptive of the progress made during the year in the design, construction, and performance of naval vessels, and in their armament, equipment, and machinery; together with some interesting data relating to the manœuvering powers of ocean steamers. These Notes have been drawn from administrative and parliamentary reports, budgets, professional journals and publications, and communications from persons engaged in professional or mechanical research.

R. P. Rodgers,
Lieutenant, U. S. Navy, Chief Intelligence Officer.

ERRATA.

Page 3, eleventh line from bottom, for "to that" read "from that."
Page 60, third line, sixth paragraph, omit the comma after "to."
Page 60, sixth line, sixth paragraph, omit the comma after "engine."
Page 63, sixth line, third paragraph, for "Achill's squadron" read "Achill squadron."
Page 85, the foot-note, "See plate 5, chapter IV," should be on next page.
Page 99, tenth line from bottom, for "one them" read "one of them."
Page 117, last line, for "meetings" read "meeting."
Page 126, first line, for "defends" read "defend."
Page 246, first line, for "insufficien" read "insufficient."
Page 250, fifth line from bottom, for "metres" read "meters."
Page 252, eleventh line, second paragraph, for "in te" read "in the."
Page 298, Table III.—Charleston and San Francisco—Stern posts—Where cast, for "Union Iron Works" read "Pacific Rolling Mills."
Page 400, fifth line, second paragraph, for "movee" read "move."
Page 421, interchange "Fig. 1" and "Fig. 2" below the cuts.
Page 441, under "France," third line, fourth paragraph, for "Baie" read "Bay."
Page 458, last table, second column, for "34 points" read "24 points."
Page 459, third line, for "27 feet beam" read "47 feet beam."
Page 463, in table, Richmond Hill—Beam, for "27" read "47."

I.

NAVAL MOBILIZATION.

By Lieutenant S. A. STAUNTON, U. S. Navy.

To build ships and guns, to equip arsenals, and to train officers and men to individual excellence and skill, are not alone sufficient to perfect a navy for the highest demands of warfare. The naval constructor, artillerist, and drill-master provide the instruments which the student of naval warfare employs; but it is the function of the latter to point out the manner in which this war material should be organized and used. He determines the proper proportions which the several types of ships and arms should bear to each other, and the condition in which they should be maintained; the strength of the personnel in activity and in reserve; the quantity of ammunition and stores to be kept in readiness, and the capacity of the arsenals and other war establishments for repairs and supply, and the relation between offensive and defensive strength. He studies the strategic value of fortified harbors and coaling stations, and the plans of campaign to be followed when circumstances shall bring upon the navy of his country the ultimate test of war.

The investigations of the student of warfare both precede and follow the creation of war material, although they do not deal with the technical problems included in the several stages—design, manufacture, and test—of that creation.

They begin upon the broad plane of national policy, and take account of the interests, safeguards, and dignities which it is necessary to assure. Assuming the intentions and dispositions of foreign powers, and knowing their present naval strength and its probable future development, these studies include a series of hypothetical cases, in which possible or probable complications may have led to the rupture of peaceful relations. A certain rating in naval strength is to be adopted and adhered to. This depends upon the position which the country proposes to assume, and the chances of making alliances with other naval powers, or of meeting an enemy's allies. It may be proposed to maintain a navy capable of coping with any two foreign navies; or a nation may be satisfied with equality to any one of her possible foes, and trust to friendly alliances to meet hostile alliances; or, with still greater modesty, a force adequate for defense in the event of war may be deemed sufficient. The problem is one of varied presentation. Commercial and colonial protection embarrass it. Opinions concerning it, even those of professional men, would be numerous and conflicting. But it is not probable that any individual or number of individuals, with the responsible charge of presenting a scheme for the creation of a naval force, would make that force too small for the proper defense of the coasts against the naval attack of its most powerful possible enemy. Capacity to meet that demand would be in any case the minimum of naval strength.

Such conclusions, based upon data partly known and partly assumed, determine the strength and composition of a naval force.

The scheme thus presented, and approved by the supreme power of the State, is placed in the hands of the technical experts—constructors, artillerists, and engineers—of the naval establishment for practical execution; and the student of warfare passes to a new series of studies, based upon the capacities offensive and defensive of the fleet thus called into existence.

These latter are war studies pure and simple. The previous considerations, dealing with the position which the country is to take as a naval power, have been semi-political; but these are entirely military, and have as their sole end to perfect the organization of the navy, and to increase its capacity for action. They are naturally divided under two principal headings:

(1) The degree of readiness and preparation in which a navy can be maintained without exceeding the reduced expenses of a peace footing, and the best methods of most rapidly placing it on a war footing.

(2) The actual operations of war, such as battle, blockade, descents upon an enemy's coast, assaults upon his fortified ports and arsenals, home defense, cruising against his commerce, and protection of one's own lines of trade.

The mere outline of these divisions is sufficient to indicate the high importance of the studies and conclusions which are intended to control the preparation for war and the conduct of war. Celerity of action is of prime necessity. All navies on a peace footing are to a greater or less degree unprepared for immediate service, and that power which first gets its squadrons on the high seas has gained an immense advantage. They can attack the enemy's commerce, threaten or assault his coasts, defeat and perhaps destroy or capture that fraction of his fleet first equipped and sent against them, and seize coaling stations and strategic points. If to a perfected organization for rapidly placing a navy on a war footing, there are added carefully devised plans of operations, strategic and tactical, to meet the varying conditions of possible future wars, then human ingenuity and skill have done all they can to secure naval preparation.

The duties thus briefly outlined should be assigned to a Naval General Staff. One man can not deal with them all. The chief of the general staff may and should *revise* all studies and plans; but he must have trained and competent subordinates to prepare them. A vast quantity of information must be collected and collated. This is the function of the Intelligence Office, and upon this foundation of accurate knowledge the General Staff bases its studies and programmes. Intelligence work is therefore of first importance, and the Intelligence Office should be a branch of the General Staff, and directly under the authority of its chief.

The importance of this purely military feature of a naval establishment has increased with the complication and cost of war material. The fiscal and mechanical interests now involved in the creation of navies are so great, that military interests stand in danger of being overlooked. The constructor and engineer have been quoted more frequently than the admiral, and zeal in the *use* of ships and guns has seemed at times likely to be overshadowed by enthusiasm in their *production.*

In the days of self-supporting sailing ships, method was not so indispensable, although even then it made important contributions to success; but in these days of mastless armored ships, of coal and countless mechanisms, torpedoes, electricity, and rifled guns, a dozen shops and factories contribute to the outfit of a single ship, and a misfitting valve may cause disaster. Method, the most refined and careful in detail, and the success of which is tested by experiment and manœuvre, is absolutely requisite.

The organization of these methods and of the trials and manœuvres which test their fitness and value has no direct connection with supply. It does not interfere with designing and building, with recruiting and training, or with any other process of production; but it indicates how and where and when the results of the several processes of supply in ships, men, guns, and stores should be placed at the disposal of the naval commander in order to secure rapid, concerted, and efficient movement. Its character is different to that of other duties, and unless specially assigned to a military office which deals with it exclusively, it is almost invariably neglected; and this office should be that of the Naval General Staff. Lord Charles Beresford declares that the fact of not having in England an efficient Intelligence department (by which he means a General Staff) is "absolutely criminal," and he says: "It is the directing brain, the central intelligence, which foresees, prepares, and issues orders for action in all contingencies. It should think out in peace all the problems of war, and be able, the moment war breaks out, to use instantly every available ship to the greatest possible purpose against an enemy."

The chief of the General Staff should be a competent flag officer; one who would have the confidence both of the government and the service.

These studies which deal with the most effective use of a navy have been divided above under two headings, which may be epitomized as—

(1) The preparation for war.

(2) The actual operations of war.

The test of the first is mobilization; that of the second is mimic warfare—"naval manœuvres"—which have now become a regular annual exercise in all foreign navies of the first and second rank.

The test of the first can be as effective in time of peace as in time of war. The same dock-yard processes are required whether a ship be fitted out for summer manœuvres or for battle.

The test of the second must necessarily be to a great extent incomplete and unsatisfactory, since real battles are not decided by arbitrary rules; but it affords opportunities for determining the enduring qualities of ships under war conditions, the adequacy of the arrangements for their supply, and the value of cruisers and dispatch vessels in keeping touch with the enemy and obtaining information, which are at the present day generally recognized as being of the utmost value.

Naval mobilization, the test of naval preparation for war, is the theme of this paper.* It may be described, in a word, as the art of passing a naval force from a peace footing to a war footing; and its full discussion includes not only the manner of executing this process, but also the previous organization of arsenals and establishment of depots necessary to keep the force at all times up to that standard of readiness for mobilization which has been decided upon as a feature of naval policy.

The entire subject may be considered under the following heads:

(1) Classification of ships in reserve, order of surveys, execution of repairs, etc.
(2) Condition of ships as classified in the several divisions of the reserve with regard to—
    Machinery.
    Batteries, both principal and secondary.
    Small-arms and equipments.
    Ammunition of all kinds.
    Equipment of vessel.
    Torpedoes and discharging apparatus.
    Coal.
    Machinery and equipment stores.
    Complements of officers and men.

---

* It is intended here to deal more particularly with the material of a naval force—ships, batteries, equipments, and stores—than with the rapid supply of officers and men.

Naval training and the organization of reserves were discussed at some length in No. VII, General Information Series, Office of Naval Intelligence, 1888. But the mobilization of ships and of the personnel which is to man them are so intimately connected, merging, in fact, when the pennant is hoisted, into a single operation, that it is not always consistent to entirely separate them.

(3) Supplies in depots at arsenals and stations of—
  Coal.
  Machinery and equipment stores.
  Food.
  Clothing.
  Facility of obtaining under war conditions new supplies, and relation of amounts on hand to the capacity of supply.

(4) Supplies in arsenals and magazines of—
  Guns and mounts (for auxiliary cruisers).
  Small-arms and equipments.
  Ammunition of all kinds.
  Manufacturing capacity of war material (especially ammunition), and the relation of this capacity to quantities kept in store.

(5) Coal transport and systems of coaling at sea or off a port, as when blockading.

(6) Submarine defenses, means for obstructing channels, mine depots.

(7) Rendezvous of active fleets, requisites of this rendezvous, and advantages that it should offer.

The systems and practices obtaining in several of the principal foreign navies to secure rapid and effective mobilization are briefly sketched below:

ENGLAND.

The nine iron-clads kept in commission as Coast-guard district ships constitute the First Reserve. They are commissioned with reduced complements and are constantly ready for service, filling up their crews upon demand from the Coast-guard men of their districts. These nine ships constitute the reserve squadron, under the command of the Admiral Superintendent of Naval Reserves.

Ships not in commission are placed in four classes of the Steam Reserve, as follows:

First Class.—Ships inspected and passed as ready for commission. These should not be confused with the ironclads of the First Reserve (Coast guard) mentioned above.

Ships in the First Class of the Steam Reserve are complete in all respects for immediate commission. They have one-third of the engineers' force on board to look after machinery and boilers, and a few other men as care-takers. Crews are not maintained for them, but it is expected that there will be enough men available at any time to man them within forty-eight hours.

These are men in depot ships and barracks subject to draft, men under training, men who could be replaced by pensioners, and the surplus of Coast-guard men after manning the district ships. Vice-Admiral Hoskins, a lord of the admiralty, in his testimony before the select committee on navy estimates in 1888, said that this matter received constant attention, and was kept up to date by the mobilization department.

The stores for ships of the First-Class Steam Reserve are kept separate from the general stores of the dock-yard; each ship's allotment laid apart ready to be placed on board without delay.

Second Class.—Ships ordered to be prepared for the First Class of Steam Reserve or for commission.

Third Class.—Ships capable of being fitted for sea service, but not ordered to be so fitted.

Fourth Class.—Ships unfit for further service at sea.

The Second Class may include ships upon which repairs have not been commenced, but in such event they are the ones to be first brought forward for repairs and the amount of work to be done upon them is comparatively small.

Ships in the Fourth Class need not be considered; they are practically canceled from the navy list.

Ships finishing their first commission and believed to be in good condition are placed in the Second Class of the Steam Reserve. The following work is done by the crew before they are paid off:

The spars and standing rigging are overhauled, and if in good condition are refitted and replaced.

The sails and running rigging are landed for survey.

The boats are landed for repairs and the chain cables for testing.

Movable furniture and fittings are landed for renovation and repair.

All coal is removed.

The guns and their carriages are examined, and if repairs are not needed they remain on board.

Machine-guns, small-arms, and all ammunition are sent into store and magazine.

The boilers are emptied and cleaned, and the machinery is opened up for inspection and for such repairs as are necessary to place it in serviceable condition.

After the ship has been paid off she is docked, and a further and thorough survey of hull and machinery is made. Estimates are prepared showing the expense of the work which will be absolutely necessary to make the ship efficient for further service; and upon the approval of these estimates, the ship is repaired with the least possible delay, and if not commissioned at once, is passed into the First Class of the Steam Reserve.

Ships finishing a commission after thorough repair are dealt with according to the state of their boilers. If these are fit for another commission the ship is paid off into the Second Class of the Reserve, surveyed, repaired, and passed into the First Class as described above. If the boilers are not good enough for another commission, the ship is paid off into the Third Class of the Reserve.

Ships that have served two commissions without thorough repair, and ships that are to have a change of armament or other extensive alterations, are paid off into the Third Class of the Reserve. They are stripped to their lower masts and all stores and armament are removed.

All ships passed into the First-Class of the Steam Reserve, all new machinery of other ships when completed, and all machinery which has been extensively repaired, is turned over to the responsible charge and control of the Captain of the Steam Reserve. When this transfer is made a sufficient staff of engine-room artificers and stokers belonging to the Steam Reserve is sent on board, to enable the chief engineer of the ship to put her engines and boilers in the state of preservation directed for ships in the class in which she is placed.

A chief engineer is always attached to a ship receiving new machinery or having her machinery repaired. This officer and the next in rank are examined as to their acquaintance with the machinery details of the ship before she is passed into the First Class of the Steam Reserve, or if subsequently appointed, before she is put in commission. They must obtain certificates in the prescribed form that they are conversant with the structure of the ship under the engines and boilers, and all details of valves, cocks, water-tight doors, sluices, pumps, etc., and the systems of flooding and ventilating. They must produce sketches and drawings, made by themselves, of the more important fittings. A chief engine-room artificer placed in charge of the machinery of a ship must obtain a similar certificate.

Engineer officers appointed to ships in the Steam Reserve are, as nearly as the exigencies of the service permit, to be kept constantly employed in their respective ships. The same rule is to apply to the artificers and stokers detailed for the care and maintenance of the machinery of ships in the Reserve. They are to be changed only when the exigencies of service render it absolutely necessary, and then only a few at a time, so that in the event of a ship's being placed in commission she shall have always a certain number of men attached to her who are fully acquainted with the details of her machinery and boilers.

The machinery of ships in the First Class of the Steam Reserve is to be maintained in such condition that it may be prepared for any service within three days. The ships placed in this class are expected to be quite ready for the pennant; but among 34 ships given in the Army and Navy Gazette of March 30, 1889, as so classified, five were waiting for their guns. The military status of these ships is not therefore well defined by the existing classification. They are turned over to the Captain of the Steam Reserve for administrative reasons, but they are not ready for commission, and they ought to be placed on a separate list.

The percentage of the naval strength kept in the First Class of the Steam Reserve is not fixed. It is apparently more a matter of chance and politics than the result of any well-defined scheme.

Torpedo boats are carefully overhauled after every period of service, needed repairs are made without delay, and great care is taken to protect both hull and machinery from deterioration, and to keep them in constant readiness for use.

As to the amount of manufactured ammunition kept in magazines on shore, there seems to be no well-defined system beyond that produced by the simple relations of demand and supply under peace conditions; the minimum demand in this case being the quantity necessary to commission all the ships in the First Class of the Reserve.

The rapid changes in armament give the War Office establishments all they can do to meet current needs; and improvements in powder, and experiments with different high explosives, justify caution in manufacture until a greater number of doubtful questions have been settled.

The industrial and commercial facilities of Great Britain render it quite unnecessary to keep on hand large supplies of food, clothing, or coal for naval use in the home ports.

The Director of Contracts at the admiralty stated before the select committee on naval estimates in 1888 that he could supply thirty armed cruisers with all items of the navy rations for six months in eight days by outside purchase independently of all naval resources. This would include, among other items, nearly 1,000 tons of biscuit.

Complete medical stores for 42,000 men are kept packed, at different points at home and abroad, ready to go on board ship in twenty-four hours. These stores are not allowed to deteriorate; any medicines or appliances that might be injured by age are issued for use and replaced by fresh purchases.

Permanent supplies of all kinds at dock-yards abroad and at foreign coaling stations depend upon the special circumstances of each case.

The British naval manœuvres of 1888 did little towards solving the vexed question of coaling ships at sea. It was attempted, but without success, and the blockading ships were obliged to go in turn to adjacent anchorages to take coal from the colliers. To use the language of Broad Arrow, "The safe and speedy transference of coal from a collier into a war ship when at sea is a problem the solution of which has not yet even been approximated to."

It seems also that the coaling facilities at the home ports were shown to be inadequate, and at Chatham, Portsmouth, and Portland railroad and pier accommodation is to be increased at considerable cost. Many other defects exhibited by the naval manœuvres will be mentioned in the comments under that title.

FRANCE.

A decree of July 13, 1884, classifies ships in Reserve in three categories:

(1) Ships that in forty-eight hours at latest, after completing their crews, can be ready for sea. They are anchored in the roadstead, and are practically in commission with reduced crews, numbering from one-half to two-thirds of their full service complements. The number of officers is also somewhat reduced.

This reduced crew is thoroughly drilled, and is organized for immediate expansion to a war footing. The ship has her coal on board and a certain quantity of stores and provisions; also, probably, a partial supply of ammunition. She is entirely in a military condition, and is required to go to sea at least once every three months for target-firing and general exercise.

(2) Ships that are entirely prepared as to material, and that can be ready for any service in ten days at farthest after receiving their crews. They have a fifth of their crews and one-half their engine-room force on board, and their officers are, a commander, a lieutenant, a doctor, paymaster, and engineer.

They have reduced quantities of stores and may lie in the roadstead or be moored within the military port. Battle-ships in this category are commanded by an officer of the grade appropriate to their command when commissioned, and have a second in command and a lieutenant and staff officers as above. The two line officers may be chosen by the commanding officer.

(3) Ships whose machinery and boilers are in perfect condition, and which have on board all material and stores not susceptible of deterioration, and can be ready to take the sea in twenty days after receiving their full crews. They have only enough men on board to take care of the ship and her equipments.

These three categories of the Reserve include all vessels, not fully commissioned, that may be said to be in a military condition. The time qualifications necessarily exclude ships upon which extensive work is in progress. These latter are also placed in three classes, viz, those which are disarmed (laid up), those which are completing after launching or extensive repairs, and those which are fitting out for the pennant.

M. Menard-Dorian, in his excellent report on the marine budget, in 1887, said that the department of the marine had placed all the armored battle-ships and coast-defence vessels not in commission in the Second Category, and he questioned the adequacy of the organization which expected to get them to sea in ten days. But this doubt referred more to the personnel than to the matérial. The mobilization of 1888 showed that the existing system met easily all demands affecting the latter.

The maintenance of armored ships in the First Reserve has been practiced in the French navy under former ministers of marine and has encountered only one serious objection. There is always a disposition to utilize them to a certain extent as receiving ships, and this rapid change of men is most unfavorable to obtaining for the reduced crew that practical experience and *esprit de vaisseau* which the nucleus of a ship's company should have. This, however, is an evil of administration which might readily be remedied.

M. Menard-Dorian advocates a return to the system of Admiral Aube, which was to have no battle-ships in the First Reserve, properly so called, but to maintain a certain number in a condition slightly advanced beyond that of the First Reserve, in commission for actual cruising service, but with reduced complements, the only change from a condition of full armament being in the number of the crew. They would be *en effectif réduit de mer* instead of *en effectif réduit de rade.* Mobilization for them would mean only the filling up of crews to their full complement. The scheme would keep a greater number of vessels in permanent commission without increase of expenditure, and would thus increase the size and value of the squadron of evolution. It should be remembered in this connection that the French crews have been for the last hundred years, and still are, somewhat larger than the crews of ships in other navies.

The following is suggested in the same report as a suitable composition for the reduced crew:

All the first masters, masters, and second masters, unless their number exceeds three.

One-half the quartermasters of all specialties, except mechanicians, helmsmen, signal men, and caulkers.

One-half the topmen in square-rigged ships and one-third in those which are mastless or fore and aft rigged.

One-half the rated gunnery men and all the powder division.

One-half the rated torpedo men.

One-half the small-arm men.

All the engine room force, except firemen and coal heavers, of which one-half should be retained.

All helmsmen and signal men.

One-half the carpenters.

One-half the rated sailmakers, and two unrated men of that specialty.

All the caulkers (necessary in case of fire).

All the clerical staff.

One-half the deck sailors (men without specialty) and apprentices.

Taking as an example the *Amiral Duperré* with a complement of 25 officers and the following men: Ten first masters, 7 masters, 51 second masters, 102 quartermasters, 414 seamen, 43 landsmen and apprentices, 6 scattered rates, a total of 633, and applying the above assignment, the reduced complement would be something over 400 men, and the saving in cost, counting two months of full commission (for the summer manœuvres) and ten months of reduced complement, would be 25 per cent.

The quantity of ammunition, stores, and provisions kept on hand is probably abundantly large. Judging from the statements of critics of the administration of the marine, it is frequently too large, resulting in great loss from age and deterioration.

M. Gerville Réache in his report of 1888, and M. Paul Borde in *Les Abus dans la Marine* (Calmann-Levy, Paris, 1889), go fully into this subject. The questions they raise are rather those of fiscal economy than of mobilization, but an excess in one place may be accompanied by a deficiency elsewhere, and it shows the system to be defective.

Several tests have been made within the last few years to determine the actual degree of readiness for service in which the French ships are maintained.

At the end of the manœuvres of 1888 the *Inconstant* in the First Category of the Reserve was ordered to be placed in commission with all speed and sent to the coast of Algeria to relieve the *Faucon*. The result was very satisfactory. Instead of the forty-eight hours accorded vessels in her category for preparation, she was ready to sail in twenty-four.

It was intended to repeat this experiment on a larger scale with eight ironclads, the *Caïman*, *Terrible*, *Trident*, *Richelieu*, *Friedland*, *Bayard*, *Duguesclin*, and *Triomphante*, all at Toulon, but for some reason, probably because of the expense, this was not done.

In May, 1888, the Préfets maritimes of Cherbourg and Brest received telegraphic orders to put at once in commission the coast-defense vessels *Fulminant* (at Brest) and *Tonnerre* and *Furieux* (at Cherbourg) and to send them, as soon as they were ready, to join the flag of the admiral commanding the Channel squadron.

The orders were a complete surprise, but two days afterwards the three vessels received their crews. The time that elapsed before they were completely ready to join the flag at sea was not stated.

The mobilization of all the ships at Toulon in the Second Category of the Reserve in August, 1888, will be fully described under the title "Naval Manœuvres." It was accomplished with great speed, the last vessel sailing from Toulon for Hyères Roads fifty-two hours after the signal had been given; but like the English operations of the same year, it had been for weeks anticipated and discussed.

A writer in the Yacht finds the principal difficulties in rapid and effective mobilization to lie with the personnel. He thinks both men and officers should become more familiar with their ships than is possible under the existing organization. He deems modern ships so complicated and difficult as to make this individual knowledge an absolute requisite; and he suggests the breaking up of the naval barracks on shore, and the assignment of all men in active service to the ships of the fleet in reserve.

Lieutenant Weyl, the well-known writer, whose editorials in the Yacht always command respectful attention, says that the great complexity and variety of modern ships and the weapons which they carry render greater care and a more specialized training necessary. What was sufficient for the old ships, simple in type and similar to each other in battery, construction, and equipment, no longer answers our purposes. We find it impossible to count upon the speedy mobilization of ships which are laid up without crews in the dock-yards, and we are confronted with the double obligation of taking constant care of the material, and of maintaining in each ship a group of trained men, familiar with all the details of the vessel and capable at any instant that she is called into commission to manage her varied mechanical apparatus and to teach others to manage them. He emphasizes the importance of keeping a reduced crew in each one of the new ships, and thinks that sufficient knowledge of the ship to assure her safety from the day of mobilization can be obtained in no other way. She may go into an action in two days after hoisting her pennant; and ignorance of a valve or of the mechanism of a water-tight door might cause her loss from an injury that otherwise would be of small importance.

An order given in 1888 directs that every ship in readiness for service should be commissioned once during the summer and tested at sea.

GERMANY.

In the German navy, as in the German army, the most complete and effective preparations exist for mobilization in time of war. In six or eight days the entire German fleet in the first class of the reserve can take the sea on a war footing.

A conference held at Kiel in September, 1883, by the chief of the admiralty and the principal flag officers of the German navy, decided that all the vessels suited to modern war purposes should be kept in thorough repair, ready for immediate war service, and that the complete outfit for each vessel should be prepared and placed either on board or in separate store-houses close at hand; that the officers and men for each ship should be detailed beforehand—from the active navy for ordinary service and from the active navy, the reserve, and the seewehr for extraordinary service.

A report made in 1884 says:

> The general underlying idea of the German system is that the ships of the navy are purely for war purposes, and are only to be employed in time of peace in cases of special necessity and for training. Thus no foreign squadrons are maintained except the one in China and a squadron of small vessels on the west coast of Africa recently established. Ships are sent abroad for foreign service only as occasion requires. The whole of the remaining ships which can be manned form during the summer months a squadron of evolution and practice, going into commission in April and going out again in October, their crews going then into barracks, which are organized exactly as are those of the army.

Each ship has a special house, called a " ship's room," in which her equipment and stores are so arranged that they can be obtained without confusion or delay. Every article that is to go on board when she is commissioned, except coal, provisions, nautical instruments and charts, guns, ammunition, boats, and spars, is kept in this room neatly stowed, and in most perfect order and condition. Even the officers' bedding and mess furniture are stored here; but the men take their bags and hammocks to the naval barracks.

Each ship in the German navy is assigned to a particular port, Kiel or Wilhelmshafen, where she always goes out of commission, and at which she is always again commissioned. When her pennant is hauled down, her crew dismantle her, replace the articles in the ship's room, the boats in the boat-house, the spars in the mast-house, and the battery and ammunition in the artillery store-house and magazines.

Everything is at once overhauled and surveyed. Needed repairs are executed, and condemned articles are replaced from the general store-house. The whole outfit of the ship's room—rigging, sails, all stores, furniture, hammocks, bedding, mess gear—everything except battery, boats, etc., as specified above, is put in immediate condition for re-issue.

The ship's rooms are low, one-story buildings placed convenient to the wharves at which the ships lie when arming.

Each one is separate and has a separate entrance, which is kept locked. No unauthorized person is allowed to enter, and no article can be taken from the room for conversion to any other use without a requsition of the same form as that prescribed for the transfer of an article actually in service on board a ship in commission.

When a ship is to go into commission, her captain sends the officers of the several departments to the ship's room to verify the invoices in the presence of a representative of the dock-yard. When these are reported correct, the key is turned over to the captain of the ship, who causes the stores to be transferred at his convenience and discretion.

This system is of comparatively recent adoption in the German navy. It has the disadvantage of requiring more space and increasing the first cost of building store-houses; but when once established, loss of stores is diminished and labor and time are saved. All the articles of value on a ship's invoices at the end of a cruise, and all special fittings, are saved for the next commission instead of being lost or misplaced, as too frequently occurs with a different system; and the outfit can be placed on board much more rapidly from a special store-house than if issued from general stores.

At first the system met opposition in Germany, but now it is much liked.

When a ship goes out of commission her guns, principal and secondary, are sent to the artillery store-house, and with their carriages and equipments are overhauled and placed in readiness for further service. Near by is another store-house divided into rooms marked for the ships assigned to the station. To this house the repaired and completed battery for each ship is taken and stored in its proper room, everything being in complete readiness to go on board. In the second story of this building are racks for small-arms, which are placed apart, each ship's outfit by itself. No one is permitted to enter this building without a special order from the commandant of the dock-yard.

Partial or entire batteries are kept on board ships in Reserve, especially in the First Class, as will be explained hereafter.

The torpedo store-house is similar in arrangement to the artillery store-house.

Boats, if worth repairing, are not allowed to fall into decay, but are sent at once to the boat house, where they receive the necessary attention, are painted, supplied with all their equipment, and stand under cover ready for instant service.

The system is thorough, and tends to careful management as well as to readiness for service. Every article when issued from the general stores for the equipment of a ship receives an individuality which it maintains until condemned as unfit for further service. It always belongs to that ship, is always in somebody's responsible charge as forming part of that ship's outfit, and can not be diverted to other purposes. On the other hand every ship has, during its life time, whether in commission or in reserve, its complete equipment and outfit of non-perishable stores, either on board or laid apart in special store-rooms packed and tallied and in perfect condition. The advantages of such a method in avoiding confusion are enormous. German officers say that aside from its military advantages, which all recognize, it is much less costly, much less troublesome, and much more convenient than the old way still followed by other powers. When a ship is in commission her ship's rooms assigned to her ordnance and stores remain empty.

Ships in Reserve in the German navy are placed in three classes These include all completed ships, not in commission, except those which are actually undergoing extensive repairs or alterations.

Every ship, when put out of commission, is placed primarily in the Third Class. But this rule does not apply to school and practice ships and surveying vessels, which are regularly in commission for a portion of each year. When laid up in the fall they are at once refitted and placed in the Second Class in readiness for service on the first of the following April.

The ship when so placed in the Third Class is at once surveyed, and a report is made to the Admiralty of her condition, and upon this report the Admiralty decides in what Class of the Reserve she shall be placed. This classification of ships upon which there has been no time to execute repairs depends apparently upon the length of time which would be necessary to fit them again for service in the event of an emergency.

All ships under these circumstances (just out of commission) require more or less repair and refitting. When this work upon a ship in the Second or Third Class is so far progressed that it may be finished in two weeks, the fact is reported by the dock-yard authorities to the Admiralty, in order that the latter may decide in which Class of the Reserve she shall eventually be placed. A ship assigned to any Class of the Reserve must be immediately put in a condition to correspond to the requirements of that Class.

Ships in the First Class of the Reserve must be in complete readiness for sea; their machinery in such condition that they can steam in forty-eight hours; sufficient coal on board for twenty-four hours' full steaming, and coal always at hand in the dock-yard to fill their bunkers; of non-perishable stores which do not suffer loss or deterioration they shall have six months' supply on board; other stores are supplied from time to time, and provisions are obtained only for current use.

Their principal batteries are kept on board; also such guns of their secondary batteries as are on covered decks. The remainder and all small-arms are kept in the respective rooms in the artillery store-house.

All powder and fused shell are kept in the magazines and shell-houses on shore ready for issue. Grape-shot and armor-piercing shell (not fused) are kept on board. Dummy cartridges and shell are supplied for exercise.

Upon the admission of a ship to the First Class of the Reserve she has a trial trip of at least six hours' duration, of which three are under full steam. All auxiliary engines and machines are tested at the same time, and the reports are sent to the Admiralty. A similar trial takes place annually. The standard compass must be adjusted and corrected and tested on the trial trip, and subsequently verified at regular intervals.

Three or four ships of the same type and a dispatch vessel, all in the First Class of the Reserve, form a reserve squadron organized and administered as a unit. To each ship is allotted the nucleus of her crew, composed of petty officers and leading men. These several nuclei are quartered in, and borne upon, the books of one of the ships, the flag-ship of the reserve squadron, commanded by a captain, who commands the squadron. The flag-ship has a full crew always on board, and goes to sea once a year for target practice.

Care is taken to preserve the training and separate organization of the several reduced crews, which are required to maintain their ships in good condition.

In the event of mobilization a lieutenant from the flag-ship goes to each of the other ships as executive officer. Commanding and other officers are ordered to them, and the crews are filled up from the sailor divisions quartered in the barracks on shore. In 1887 the reserve squadron at Wilhelmshafen was composed of the gun-vessels *Mücke*, *Viper*, *Salamander*, and *Camäleon*. The *Mücke* (flagship) had a full crew, and ten men belonging to each of the others. The remainder of the crews of the *Viper*, *Salamander*, and *Camäleon*, quartered on shore, came on board their ship once a week for battery exercise. This squadron was mobilized every summer for exercise and manœuvres, and could at any time go to sea ready for service in thirty-six hours.

Ships in the First Class of the Reserve are periodically inspected, their holds broken out, stores overhauled, etc. Their condition is presented to the Admiralty in quarterly reports. They are removed from the control of the dock-yard.

A ship in the Second Class of the Reserve must be in such condition that she can be ready for service in three weeks. No stores or coal are on board. The battery may or may not be on board. It is a question of maintaining in good condition both ship and guns. If the guns or their carriages would be injured by remaining on board, or if they would cause injury to the hull, they are removed. Generally no guns on uncovered decks are kept on board. All guns and carriages which are removed, their equipments and fittings, and the machine and rapid-fire guns of the secondary battery and all small-arms are in the ship's room in the artillery store-house on shore. All parts of machinery and all heavy spare parts are on board.

If the machinery of a ship has had extensive repairs, or if for any reason the dock-yard officials consider it desirable, she has a six hours' steam trial before she is placed in the Second Class of the Reserve. Her exact condition is placed on file at the Admiralty in the form of answers to a set of questions sent to the dock-yard officials. When a ship remains continuously in the Second Class Reserve, a similar set of questions is sent by the Admiralty to the dock-yard every 1st of March in order to assure her maintenance in proper condition.

Ships which are to have extensive repairs or alterations, not to be immediately executed, are placed in the mean time in the Third Class of the Reserve, and are put in the following condition: They are painted gray, with white ports. The copper of wooden or sheathed ships above the water-line (the ship being light) is removed, the seams carefully calked, and the planks painted with wood-tar. The ship is stripped to her lower masts; but iron yards, anchors, etc., may remain on board. The machinery may be taken apart for better preservation. The heavy guns and carriages can remain on board if they do not injure the ship or interfere with work. The secondary battery and all equipment in store on shore. No coal or stores on board.

Torpedo warfare, and the care, management, and preservation of torpedo-boats, has received more attention in Germany than elsewhere. The boats are habitually kept in the water and in readiness for service. At Wilhelmshafen a small dry-dock has been built especially for torpedo-boats near the basin in which they are moored. The store-houses for torpedo material and the quarters for the boats' crews are also near this basin.

Coal and other consumable material for the fleet is kept in store, each kind in its own place and in sufficient quantity. As far as possible, even with these stores, their separate supplies are allotted to ships in the First Class of the Reserve.

A memorial to the Reichstag in 1884 dwelt upon the necessity for more elaborate preparations in regard to victualing and clothing. There was clothing then on hand for 11,500 men. The increase of force in the event of mobilization would have been 19,000; hence a further supply of clothing for 7,500 men, at a cost of 780,000 marks, was necessary in order to have enough to meet the demands of war.

The Germans make frequent tests of the efficiency of their organization.

In 1885 a reserve squadron, composed of the ironclads *Bayern*, *Sachsen*, *Würtemberg*, and *Baden*, and the dispatch-boat *Zieten*, was formed, to ascertain the rapidity with which the most formidable and most heavily armed ships of the fleet could be commissioned for service.

On the 15th of May, 1885, there took place an exercise of mobilization at Wilhelmshafen. The sailors of the station were collected in the *Place d'Armes*, and inspected by the commander-in-chief. Those men that, according to the plan of mobilization, were intended for the station of Kiel, and for the manning of ships at that port, were sent to the railway station, and exercised in embarking and disembarking from the trains. All work in the arsenal was suspended, and the workmen were assembled at their stations in the magazines and store-houses. The exercise lasted all day, and all branches of the service were inspected.

At 9.10 a. m. April 22, 1884, the chief of the admiralty, General Von Caprivi, with his aid, arrived unexpectedly at Kiel, and at 1 p. m. ordered into commission for immediate service the following vessels:

ARMORED BATTLE SHIPS.—*Baden, Sachsen, Bayern, Würtemberg.*
ARMORED COAST-DEFENSE VESSELS.—*Hümmel, Biene, Camäleon, Crocodill.*
DISPATCH VESSELS.—*Blitz, Grille.*
TORPEDO-BOATS.—*Kühn, Vorwärts, Scharf,* at Kiel; *Jäger, Tapfer, Flink,* at Wilhelmshafen.

Notice was sent to the officers and crews according to the system adopted in the army. The trains brought in the men, and in a few hours, with the assistance of the dock-yard division, the ships were equipped.

At noon April 24, forty-seven hours after the signal to mobilize, Rear-Admiral Count von Monts hoisted his flag on the *Baden*, in command of a squadron of twenty vessels, ready for war service. The vessels already in commission had joined the squadron.

AUSTRIA.

The organization of stores in the Austrian Navy is practically the same as that employed in the German Navy, differing only in matters of detail. All the stores—except ammunition, provisions, and coal—for each vessel are laid apart, are easy of access, and are kept entirely distinct from those of other ships. Ordnance stores, including small arms and equipments, are in one building, electrical supplies in another, engineers' stores in a third, and there is a larger store-house for general construction and equipment stores, including sails and rigging. Each store-house is divided into lockers or compartments, one of which is assigned to each ship. The method is the same as that of the "ship's rooms." The supplies for torpedo-boats are kept in a special building, each boat having a place assigned to it.

The fact that Austria has but one naval arsenal—Pola—at which all ships fit out, simplifies the application of this method.

Vessels in complete readiness for service are divided into two classes of the Reserve, viz, those that can take the sea in forty-eight hours, the gunnery and torpedo schools supplying their men and officers, and those, which by reason of having to drill men not already fully instructed, would need six or seven days' preparation.

The preparation for a speedy mobilization of the personnel includes a peculiar feature. Each officer in the Austrian Navy has in his possession a "war order," the contents of which are known only to the ministry of marine and to himself. It is sent direct to the officer and does not follow the usual channels of official correspondence, and it becomes operative only in the event of war, when, without delay, he proceeds to his new post and assumes his new duties.

The Austrian organization appears to be effective. It is stated that a telegraphic order from Vienna to Pola to send a certain torpedo-boat to Trieste found the boat hauled up in the storage shed with nothing on board; but it was fully equipped and reached Trieste in twenty-four hours. When the Greecian blockade was established in 1886, five torpedo-boats, ordered to proceed to Suda Bay, were equipped, provisioned, and on their way in forty-eight hours.

ITALY.

Ships not in commission in the Italian navy are classed, with respect to their readiness for service, under the following heads:

(1) Ships in Reserve, which have a reduced number of officers and from one-third to one-half of their full crews. All, or nearly all, of their stores are on board, and they can be called into service in two or three days. A ship in Reserve flies the ensign and pennant, and is to all appearances a ship in commission. She is commanded by the officer who is to command her when fully commissioned, and the officers attached to her in Reserve form part of her future detail.

(2) Ships in *Disponibilità* (disposable for service). The hull, machinery, and battery all in good condition. A ship in this class has no stores on board. One officer and a few men are attached to her, and she can be made ready for active service in a short time.

Other ships, apart from those building or fitting out, are "disarmed" (laid up). Their principal fixtures are in place; they may or may not need repairs, but they are not in a military condition.

The possibilities of the Italian navy for rapidly putting its whole force afloat are only fair. It has not yet attained the perfection of the German system, which is much admired and which it is desired to imitate. When a ship is placed out of commission she is at once thoroughly examined, and the extent of the overhauling and repairs necessary to put her into service condition is determined. Theoretically this is to be done at once, and the ship passed into the state of "*Disponibilità*" or "Reserve;" but practically the navy-yards have been so busy with the work on the new ships, that repairs have been made only when the ships were needed for service.

All articles non-consumable and of a fixed and permanent character, like gun-fittings, boats, spars, anchors, etc., called in the Italian navy articles of "dotation" or dowry, are, when allotted to a ship, inscribed in an inventory, after which they belong to that ship and no other till condemned as unserviceable. When the ship goes out of commission these articles are passed into a store-house and receipted for by the store-keeper as belonging to her. They remain on her inventory, and can not be converted to any other use without the special order of the commander-in-chief. But all perishable articles are held in general store, subject to any demand.

The Italian navy is especially well supplied with torpedo-boats, and these are distributed for the defense of the entire coast.

There are, according to the *Giornale Militare per la Marina*, an official paper, fourteen principal and nineteen secondary torpedo-boat stations.

Each principal station must furnish good shelter for at least nine coast torpedo boats; must have in the neighborhood means of hauling a torpedo-boat out of water, and of executing small repairs, and must have a supply of fresh water. It must have a magazine for twelve torpedoes with their loaded heads, and machine guns, small arms, and ammunition for nine boats; enough coal and machinery supplies to supply nine boats three times; storage for two thousand rations; quarters for forty-two men, and mess facilities for sixty; compression pumps; a signal mast, and day, night, and sound signals.

Each secondary station must give shelter for three boats, and have fresh water, coal, and machinery supplies for the same number. They should have a signal mast and signals, and quarters for two men.

Each principal station is the torpedo headquarters of a district of the coast, and the secondary stations in the district are attached to it and under its control. The commanding officer of a principal station has the duties and powers of the captain of a single ship, and of a local maritime commandant in his relations with the civil and military local authorities, and with his naval superiors and inferiors. He inspects all the semaphore stations, naval defenses, and secondary torpedo-boat stations in his district once a month, cruising in a torpedo-boat, exercises all the boats frequently and causes their crews to know the coast.

Besides the proper maintenance of the torpedo-boat material and personnel in a condition for speedy passage to a war footing, he keeps a lookout from his station, gives aid when possible in the event of maritime disaster, and makes weather signals.

Part of the boats at a station are kept in commission, and the remainder in reserve.

Only a storekeeper and his assistant are kept at the secondary stations, which are intended chiefly for supply.

The arrangements which the principal maritime powers have made to assure the obtaining without delay, in the event of war, of the services of the best and fastest merchant vessels under their respective flags as auxiliary cruisers, and the provisions carried into effect for arming them and manning them, will be found in No. VII, General Information Series, page 32 *et sequitur*.

Of the systems of mobilization of the regular forces noticed, that of Germany is probably the most thorough and complete. The English method is so irregular and uncertain that it can hardly be called a "system," and in Italy the practice falls a long way behind the theory. France keeps a greater number of men afloat in her reserve ships, which is *per se* an advantage, although it may be accompanied by disadvantages of training and discipline which are of equal weight.

The following is suggested as a scheme of maintenance and mobilization suitable for a power like the United States, which possesses a navy of only moderate strength. Such a power purposely avoiding, for motives of national economy and national policy, the creation of huge armaments in time of peace, should be able to utilize to the fullest extent and on short notice the whole of its force. The divisions of the general subject suggested on page 4 are taken up in order.

First. All the ships in the Navy to be classified under the following heads:

(1) In Commission.
(2) In First Class of Reserve.
(3) In Second Class of Reserve.
(4) Fitting out or Repairing.
(5) Building, not yet Launched.

The last two heads comprise ships not in a military condition. The second and third are those with which we have to deal.

Ships of the First Class of Reserve to be capable of mobilizing in ten days, those of the Second Class in twenty days.

Each ship in the Navy to be assigned to a certain military port (navy-yard), to fit out there when new, always to commission and go out of commission there, to repair there, and to lie there while in reserve.

All plans, models, and drawings, and calculations based upon them, forming the history of the construction and important alterations of a ship, to remain always at the navy-yard to which she is assigned, and to be transferred without delay should her assignment be changed to another yard.

A ship upon going out of commission to be without classification until a complete survey can be held to determine the needed repairs, and the report approved by the Navy Department. If no repairs are needed the ship to be placed at once in one of the classes of Reserve at the discretion of the Department. Repairs, if needed, to be executed with the least possible delay, and the ship then placed in the First or Second Class of Reserve.

Second. Ships in the First Class of the Reserve to have their machinery in complete readiness for service; their primary batteries on board and enough guns of the secondary battery to instruct the reduced crew; small arms and equipments for the same purpose; no ammunition; no boats or running rigging; no torpedoes; discharging apparatus installed if not liable to deterioration; coal, perishable stores, and provisions for current use only; their outfit of non-perishable machinery and equipment stores. To fly the pennant and ensign, to be commanded by officers of the grade suited to their command when in full commission, to have two line officers and two engineers on board, one-half their rated engine-room force and one-fourth of the remainder of their crews.

Each ship in the First Reserve to go to sea once a year, run her engines for several hours at full speed, fire all her guns, and test as nearly as possible the efficiency of all her means of offense and defense.

Combinations of the reduced crews to take the vessels out in turn, or the occasion of annual manœuvres to be utilized, mobilizing the Naval Reserve and taking them all out together.

All torpedo boats and torpedo scouts and not less than one-half of the armored vessels and two-thirds of the cruisers should be in commission or in the First Reserve.

Ships in the Second Class of the Reserve to have their machinery in complete readiness for service; no guns mounted except heavy turret or barbette guns; no small arms and equipments on board; no ammunition; no boats, rigging or torpedoes; no coal or stores; a lieutenant in charge who will be executive officer when the ship is called into service; enough men to care for the machinery and heavy guns, to be quartered and messed in the naval barracks.

Ships in both classes of the Reserve to be moored head and stern in a basin or other suitable locality, and connected with the shore by floats.

A system of "ship's rooms" like that of the German navy to be established. An article when once alotted to a ship to remain always on charge, as belonging to her, until condemned as unfit for further service; to be repaired if necessary, but not to be replaced by new unless an emergency arises before the repairs are completed. Accummulation of old material to be avoided.

Third. The facility of obtaining supplies of coal, stores, food, and clothing under war conditions and at different points, to be carefully considered; and the supplies kept on hand at each point to have a direct relation to this facility. They should be large enough to meet all demands which the probable operations of war would make upon them until the new movements of replacement through commercial channels were fully established and in smooth working order. When channels of replacement may be exposed to interruptions by hostile operations, the calculation must take these chances into account.

Fourth. The batteries and equipments decided upon for the steamships retained by the Government as auxiliary cruisers in the event of war, to be kept in store, complete and ready for service. A sufficient number of small-arms and equipments for all the ships, naval and auxiliary, that could be commissioned in the event of war, to be kept in store. At least a sufficient quantity of ammunition of all kinds to supply each ship with its allowance should be kept in readiness for issue; and an additional quantity if the manufacturing capacity is not capable of replacing this allowance within two months.

Fifth. Such an organization of coal transport to be planned, as shall keep bases and cruising squadrons fully supplied. When ships are to coal from colliers, these to be of small capacity, not more than 2,000 tons as a maximum. Experiment should be made upon the problem of coaling at sea with a view to its solution. A satisfactory method of transferring coal in the open sea will be of great value to a navy which has no foreign coaling stations, and where cruisers in distant seas may have to depend largely upon captures for fuel.

Sixth. Plans of mine and obstructive defense of the principal harbors to be elaborated, mine depots completed, equipped, and stocked, electrical apparatus at hand, firing and electric-light stations selected and built, sites determined and prepared for submerged batteries of automobile torpedoes commanding the channels, battery emplacements prepared for light batteries to guard the mine fields from boat operations.

Seventh. The positions of rendezvous will depend upon the character and operations of the war. Their final selection is a part of the strategy of warfare and must necessarily be deferred until the plan of campaign has been decided.

They should offer good anchorage, plenty of room, and capacity for defense, facilities for communication and supply, and be easy of access and exit. Their positions if possible should be central with regard to the points to be covered, and should be at the same time favorable points from which to make raids or attacks.

II.

THE NAVAL MANŒUVRES OF 1888.

By Lieutenant S. A. Staunton, U. S. Navy.

ENGLAND.

THE SCHEME AND RULES.

The general scheme of the naval manœuvres was the following:

A maritime nation with whom hostilities are imminent prepares two squadrons in two ports some distance apart with the intention of sending them to sea the instant war is declared; but before their preparation has been completed war breaks out and a blockade of both ports is established. The blockaded squadrons endeavor to escape, to prey upon British commerce and ravage the British coasts. The blockading squadrons endeavor to prevent the escape of the enemy's squadrons; or, failing in this, to follow up and capture them.

Ireland was considered the enemy's country, and the ports selected for blockade were Berehaven in Bantry Bay, on the southwest coast, and Lough Swilly, on the north coast. All Irish territory was considered hostile to the British fleet and friendly to the enemy's; while all of England, Wales, and Scotland was considered friendly to the British fleet and hostile to the enemy's. No coal could be obtained from a hostile port.

Lamlash Bay, Pembroke, Plymouth, Portland, Spithead, and the Medway in Great Britain, Berehaven, Queenstown, and Lough Swilly in Ireland were considered as strongly fortified ports, in which ships were subject to attack by torpedo-boats only. All other ports in Great Britain and Ireland were considered undefended ports in which vessels were liable to all forms of attack. The field of operations was to lie between the parallels of 48 and 62 degrees north latitude, and the meridians of 3 degrees east and 13 degrees west longitnde, a space measuring 14 degrees of latitude by 16 degrees of longitude and including the British Islands and their adjacent waters.

Two fleets, each composed of battle ships, fast cruisers, and torpedo-boats, were assembled to carry out this programme: The A fleet (British), consisting of thirteen battle-ships, thirteen cruisers, and twelve torpedo-boats, at Spithead; and the B fleet (enemy's), consisting of nine battle-ships, ten cruisers, and twelve torpedo-boats, at Portland.

Vice-Admiral J. K. E. Baird was appointed to command the British fleet, and Rear-Admiral Sir George Tryon to command the enemy's fleet. The A fleet was divided into two squadrons, A^1 and A^2, and the B fleet into two squadrons, B^1 and B^2.

Rear-Admiral Charles J. Rowley was appointed second in command of A fleet, and commanded A^2 squadron. Rear-Admiral Robert O'B. FitzRoy was appointed second in command of B fleet, and commanded B^2 squadron.

B fleet was also known as the "Achill" fleet, and was frequently referred to by that name in reports and letters during the progress of the manœuvres.

A flag officer was appointed as umpire to each squadron.

The base of A^1 squadron was Milford Haven (protected by the fortifications of Pembroke) and that of A^2 squadron was Lamlash Bay, in the island of Arran. These bases are respectively 180 and 95 miles from Bantry Bay and Lough Swilly. Coal and stores were dispatched to them.

The *Nessmore* and *Oranmore*, two steam-ships of Johnson's line, of Liverpool, were chartered as colliers to accompany the fleets. The first was assigned to A fleet and the second to B fleet. The capacity of each is 3,500 tons. A lieutenant was placed in each as transport officer, and a full supply of buckets, shovels, and whips was provided. The *Oranmore* took on board at Portsmouth two large horse-boats, weighing five tons each, to use in coaling at sea.

The precise rules laid down by the admiralty for the guidance of the manœuvres, together with other detailed instructions, were confidential, but some of them were given, in a general way, to the press correspondents who were allowed to accompany the fleets, and others may be inferred from the development of the operations.

These rules do not appear at first sight to be numerous or complicated; but their construction by commanding officers proved to be of infinite diversity, and their application by the umpires was embarrassing and difficult. Much time was consumed in considering claims and counter-claims arising from differences of opinion in regard to time, distance, etc., or from circumstances where the rules failed to apply. A feeling of irritation and soreness gradually came over the officers and men of both fleets, until by the time the blockade was broken they were almost ready to fight in reality. Newspaper correspondents shared this feeling, and it is possible that the umpires were not altogether free from it.

It was ordered that no gun should be fired until ships were within 4,000 yards of each other by day, and 2,000 yards by night; and to avoid the unnecessary expenditure of ammunition, guns were to be fired only at the beginning of an action. No ship was to approach within 1,000 yards of an enemy's ship.

Should a squadron or part of a squadron be able to maintain a position for two hours within 3 miles of a squadron or part of a squadron of the enemy, numerically inferior class for class—*i. e.*, battle-ships against battle-ships and cruisers against cruisers—the fact was to be considered as evidence of the ability of the superior force to have brought on an engagement and to have obtained the advantage.

The distance of 3 miles was to be measured between the nearest battle-ships, and the umpires were to observe that the ships of the superior force were kept sufficiently in hand during the whole time to afford one another material support.

If two ironclads or one ironclad and one protected vessel could maintain a position for two hours within 3,000 yards of a single hostile ironclad, the single ironclad should be considered as put out of action. The same rule as to position and result was to apply in the case of a single ironclad against a single vessel not ironclad, either protected or unprotected; in that of two protected vessels, or one protected and one unprotected vessel against a single protected vessel; and in that of two unprotected vessels against a single unprotected vessel; but the time in each of these cases was to be reduced to one hour.

If an ironclad or protected vessel could approach an enemy's vessel at anchor in an unfortified port to within a distance of 2,000 yards, the vessel so caught at anchor was to be considered as having been rammed and put out of action.

When preying on commerce, a cruiser, in order to record a merchant vessel as captured or destroyed, must have held that vessel under her guns for an hour and a half without interference by a superior force of the enemy, that time being considered necessary to board and examine the vessel, and put a prize crew on board of her or sink her. The following is quoted from an official source:

> Vessels engaged in the attack on British commerce are not to engage enemy's vessels of war, unless for the purpose of self-defense.
>
> If an opposing vessel of superior force arrives within 4,000 yards of an enemy's vessel, whilst the latter is engaged in the capture of a merchant vessel, but before the capture is completed, the enemy's vessel must sheer off and try to escape.
>
> In war, it will be necessary to board every vessel, in order to verify her nationality; a number of vessels would certainly not remain together in the presence of an enemy's cruiser, but endeavor to escape; therefore, only one vessel is to be captured at a time.
>
> A gun is to be fired by the vessel making the capture, for each vessel which it is assumed has been captured.
>
> The following is to be considered the order of superiority of the cruisers, observing that vessels bracketed are to be considered equal in force:

1. *Mersey.*
   Thames.
   Severn.
2. *Inconstant.*
3. *Amphion.*
   Arethusa.
4. *Rover.*
5. *Active.*
   Volage.
6. *Calypso.*
7. *Mercury.*
   Iris.
8. *Cossack.*
   Archer.
   Tartar
   Serpent.
   Racoon.
   Mohawk.
9. *Curlew.*
10. *Grasshopper.*
    Sandfly.
    Spider.
    Rattlesnake.

This classification, it will be remembered, was applied to cruisers only while attacking and defending commerce, not while forming part of the squadrons, where numerical advantage became the test of strength.

Torpedo boats were each to be provided with two torpedoes fitted with safety-heads, which were not to be fired at distances greater than 500 yards. A ship struck by a torpedo was to be put out of action. After firing one torpedo a torpedo boat was to be considered out of action until she had picked up her torpedo or been supplied with another from the depot ship.

Just before firing a torpedo the torpedo boat was to whistle, at which signal the ship attacked would stop her engines to avoid the danger of striking the torpedo with the screw; and at the instant of firing, a Holmes light was to be thrown overboard. Rapid-fire and machine-guns and rifles were to be used in repelling torpedo boat attack. The heavy guns were not to be fired.

A torpedo boat under continuous fire for three minutes, at distances under 2,000 yards, was to be put out of action. If several boats were acting together, half a minute additional time was to be allowed for each additional boat, all being put out of action together.

Boats were to be considered as acting together when they were under fire at the same time; e. g., if a torpedo boat were seen and fired upon, and before her three minutes had elapsed, other boats appeared and were fired upon, the time of the first boat was to be prolonged because attention and fire had been diverted from her. But if the other boats were more than half a minute per boat behind the first, *they* would *lose* time as the penalty for attacking in straggling order. In such cases the time of declaring all the boats out of action would be after the expiration of three minutes for the first boat, and before the expiration of three minutes for the last; and would be determined between these limits at the judgment of the umpires. It is evident that rules of such flexibility, applying to data so difficult to observe and determine as that of torpedo-boat attack, were sure to give trouble; and it followed that this feature of the manœuvres was most fruitful in differences of opinion and dissatisfaction with the decisions of umpires.

Vessels which were claimed and admitted by the umpires to have been put out of action were to haul down their colors by day, and to hoist position lights at night. Torpedo boats which were decided to have been put out of action at night were to hoist steam lights. All vessels adjudged to have been put out of action were to follow the orders of the officer in command of the squadron by which they had been so put out of action.

The principal object of the manœuvres was to determine the practicability of blockading an inferior force of the enemy in his own ports under the altered conditions of warfare resulting from the introduction of steam, electricity, high-powered long range guns, machine guns, and torpedoes.

All features of naval warfare incident to the attempt on one hand to maintain the blockade and on the other hand to break it, were to be observed and reported upon. Some of these features were:

The value of torpedo-boats to blockaders and blockaded, including their capability of keeping the sea for any length of time and the endurance of their crews.

The best disposition of the vessels of a blockading force—ironclads, cruisers, and torpedo-boats—by day and night; the relative advantages and disadvantages of keeping the main body of a fleet off the port blockaded, with an inshore squadron, and of keeping the main body of the blockading fleet at a base, with a squadron of cruisers and torpedo-boats off the port, with means of rapid communication with the fleet; the attacks to which they are exposed, and the means of guarding against them.

The most efficient manner of using torpedo-boats both with the blockaded and blockading fleets.

Systems of private signals by which friendly may be distinguished from hostile vessels both by day and night.

Systems of secret or confidential signals, by which commanding officers can communicate important orders or advices.

Coaling at sea and on the blockading station.

Corollary to a failure to maintain the blockade were:

The dispositions to protect commerce and undefended ports.

The use of cruisers and signal stations to keep touch with the enemy and learn his movements, especially the movements of cruisers preying on British commerce, including the number of cruisers necessary for this purpose, and their best distribution and management.

The two fleets were to be organized and prepared in every way as if for actual war service. When all preparations were completed and all preliminaries were arranged, the two admirals in command were to report to the Admiralty. The four squadrons were then to repair to their stations—B[1] squadron to Bantry Bay, B[2] squadron to Lough Swilly, and A[1] and A[2] squadrons to the vicinity of those ports respectively, first visiting their bases at Milford Haven and Lamlash Bay and completing with coal and stores.

The information that war had been declared was to be telegraphed to both commanders-in-chief by the Admiralty; after which both were to be left to their own methods, to devise and carry out their own strategy and tactics, and to accomplish what they could with the means placed at their disposal until the close of the manœuvres. No special intelligence ships were to be supplied to the fleets, but each admiral was to use his fast cruisers to obtain information. A system of signals for communicating with the Coast-guard stations was supplied.

THE MOBILIZATION.

On Monday, July 2, the commanders-in-chief at the home ports were notified that certain ships would be commissioned on the 4th, and the officers appointed to those ships received their orders. The names of the ships to be commissioned had been known at the dock-yards since March, and much preparation had been made for the "mobilization."

On the same day (July 2) the captains of the Coast-guard district ships received orders to complete their crews and rendezvous at Spithead and Portland. Notice had been given to these officers eight days before that events might necessitate the complete arming of the ships under their command; and that they would hold themselves in readiness to carry out orders in conformity to the general scheme of mobilization.

These district ships, nine in number, and stationed as follows—the *Belleisle* at Kingstown, the *Devastation* at Queensferry, the *Invincible* at Southampton, the *Ajax* in the Clyde, the *Neptune* at Holyhead, the *Rupert* in the Humber, and the *Hotspur* at Harwich, the *Hercules* at Portland, and the *Shannon* at Bantry Bay—were, upon receipt of telegraphic orders, to complete their crews from the Coast guard. All officers and men on leave were to be at once recalled, and a list of available men was to be sent to the commander-in-chief of the squadron within three hours.

Each ship was to leave her district station at a specified hour, follow a certain programme, and reach the rendezvous, fully manned and prepared for service, in a certain specified time after first notice, which in no case exceeded one hundred hours.

This programme was successfully carried out. With the exception of a few officers of the Royal Naval Reserve, serving in several ships, the Coast guard was the only body of the naval reserves that took part in these manœuvres.

On July 3 Rear-Admiral Sir George Tryon, the Admiral Superintendent of Naval Reserves, left London to take command of B fleet. Before leaving he had caused instructions to be sent to all commanding officers of Coast guard to supply capable signal men at the new lookout points which had been established to indicate the presence of the enemy.

The ironclads *Rodney*, *Benbow*, and *Warspite* had been commissioned at Sheerness on June 20th, in order that they might get out of the Medway on the spring tides. On the 4th of July the ironclad *Northampton*, cruisers *Arethusa*, *Mersey*, *Mohawk*, *Tartar*, and *Grasshopper*, and torpedo-boats 63, 64, 65, and 67 at Sheerness, the ironclads *Collingwood*, *Hero*, and *Inflexible*, cruisers *Iris*, *Mercury*, and *Severn*, and torpedo-boats 25, 41, 42, 49, 50, 66, 72, 79, 80, and 81, at Portsmouth; the ironclads *Black Prince* and *Conqueror*, cruisers *Amphion*, *Inconstant*, *Thames*, *Archer*, *Cossack*, *Raccoon*, *Serpent*, *Sandfly*, and *Spider*, and torpedo-boats 45, 51, 52, 53, 54, 55, 57, 58, 59, and 60, at Devonport, were placed in commission.

It was intended that these new ships should be ready for service in three days, and on the 7th they were all assembled at Spithead and Portland, where they joined the nine ironclads of the reserve squadron (the Coast-guard district ships), the channel squadron consisting of the ironclads *Northumberland*, *Agincourt*, *Iron Duke*, and *Monarch*, and the gunboat *Curlew;* the flying squadron, Commodore Markham, consisting of the cruisers *Active*, *Calypso*, *Rover*, and *Volage*, and the torpedo gunboat *Rattlesnake*, tender to the *Vernon*, at Portsmouth.

Torpedo boat 63, injured by a collision at Chatham, and 65, injured by stranding at Sheerness, were replaced by Nos. 76 and 78.

The following table shows the strength and organization of both squadrons:

A SQUADRON.

Vice-Admiral JOHN K. E. BAIRD, *in command; Rear-Admiral* CHARLES J. ROWLEY, *second in command.*

Umpires: Rear-Admiral ALEXANDER BULLER, C. B., *first division; Rear-Admiral* NATHANIEL BOWDEN-SMITH, *second division.*

FIRST DIVISION.

Ship.	Guns.	Tons.	H. P.	Sea speed in knots.*	Complement.
BATTLE SHIPS:					
Northumberland (*flag*)	29	10, 780	6, 560	11. 5	710
Benbow	12	10, 600	11, 500	15. 5	503
Collingwood	10	9, 500	9, 570	14. 6	459
Monarch	7	8, 320	7, 840	12. 8	572
Conqueror	6	6, 200	6, 000	13. 5	310
Hotspur	4	4, 010	3, 060	10. 5	180
Northampton	12	7, 630	6, 070	11. 2	567
CRUISERS:					
Mersey	12	4, 050	6, 000	16.	317
Arethusa	10	4, 300	5, 500	15.	295
Rover	14	3, 460	4, 960	12. 5	376
Active	12	3, 080	4, 130	13. 1	353
Archer	6	1, 770	3, 500	14. 3	157
Raccoon	6	1, 770	4, 500	15. 6	157
Rattlesnake	1	550	2, 700	17. 3	61

SECOND DIVISION.

Ship.	Guns.	Tons.	H. P.	Sea speed in knots.*	Complement.
BATTLE SHIPS:					
Agincourt (*flag*)	17	10, 690	6, 870	11. 7	711
Inflexible	12	11, 880	8, 010	11. 5	460
Neptune	6	9, 310	8, 000	12. 3	333
Iron Duke	14	6, 010	3, 520	10. 5	482
Belleisle	4	4, 870	3, 200	10.	193
Shannon	9	5, 390	3, 370	10. 5	318
CRUISERS:					
Thames	12	4, 050	5, 700	15. 8	317
Inconstant	16	5, 780	7, 360	14. 3	614
Mercury	13	3, 730	7, 290	15. 3	276
Mohawk	6	1, 770	3, 500	15. 3	157
Tartar	6	1, 770	3, 500	15. 6	157
Grasshopper	1	525	3, 000	17. 2	61

---

* The "sea speed" of the ships and torpedo-boats in A and B squadrons is taken from the Daily News of July 13, 1888; and is probably an admiralty estimate of what the several vessels were expected to do at that time and with the conditions under which they were commissioned for the manœuvres.

TORPEDO-BOATS ATTACHED TO A SQUADRON.

	Length.	H. P.	Sea speed in knots.	Complement.
	ft. in.			
No. 25	125 0	590	18	16
No. 41	125 0	690	18.5	16
No. 42	125 0	690	18.5	16
No. 49	125 0	720	18.5	16
No. 50	125 0	770	18.5	16
No. 66	125 4	630	20	16
No. 67	135 3	660	20	16
No. 72	125 4	670	20	16
No. 76	125 3	640	20	16
No. 79	128 8	990	20	16
No. 80	135 0	1,540	21.5	21
No. 81	150 0	1,330	16	26

Nos. 25, 41, 42, 49, 67, 76, 79, and 81 were attached to first division; Nos. 50, 66, 72, and 80 to second division.

B SQUADRON.

Rear-Admiral SIR GEORGE TRYON, K. C. B., *in command; Rear-Admiral* ROBERT O'B. FITZROY, C. B., *second in command.*

Umpires: Rear-Admiral SIR ROBERT H. M. MOLYNEUX, K. C. B., *first division; Rear-Admiral* PHILIP COLOMB, *second division.*

FIRST DIVISION.

Ship.	Guns.	Tons.	H. P.	Sea speed in knots.	Complement.
BATTLE SHIPS:					
Hercules (*flag*)	20	8,680	6,750	12.5	388
Ajax	6	8,660	6,440	11	292
Hero	6	6,200	6,000	13.5	310
Rupert	4	5.440	4,630	11.5	197
Warspite	10	8,400	10,000	15.7	527
CRUISERS:					
Severn	12	4,050	6,000	16	317
Volage	12	3,080	4,530	13.1	355
Iris	13	3,730	7,330	16	276
Cossack	6	1,770	3,500	15.2	157
Sandfly	1	525	3,000	17.3	61

SECOND DIVISION.

Ship.	Guns.	Tons.	H. P.	Sea speed in knots.	Complement.
BATTLE SHIPS:					
Rodney (*flag*)	10	10,300	11,500	15	500
Devastation	4	9,330	6,650	11.8	285
Invincible	16	6,010	4,830	11.6	338
Black Prince	28	9,210	5,770	10.8	697
CRUISERS:					
Amphion	10	4,300	5,550	15	295
Calypso	16	2,770	3,720	11.9	315
Serpent	6	1,770	4,500	15.6	157
Curlew	4	950	1,500	12	97
Spider	1	525	3,000	17.3	61

NOTE.—The *Hearty*, a tug, of 4 guns, 1,300 tons, 1,800 H. P., and about 13 knots speed, was subsequently, by admiralty order, attached to B^2 squadron.

TORPEDO BOATS ATTACHED TO B SQUADRON.

	Length.	H. P.	Sea speed in knots.	Complement.
	ft. in.			
No. 45	125 0	690	18.5	16
No. 51	125 0	680	18.5	16
No. 52	125 0	720	18.5	16
No. 53	125 0	760	18.5	16
No. 54	125 0	720	18.5	16
No. 55	125 0	660	18.5	16
No. 57	125 0	740	18.5	16
No. 58	125 0	720	18.5	16
No. 59	125 0	750	18.5	16
No. 60	125 0	745	20	16
No. 64	125 3	670	20	16
No. 78	125 1	720	18.5	16

Nos. 53, 54, 59, 60, 64, and 78 were attached to first division; Nos. 45, 51, 52, 55, 57, and 58 to second division.

The two squadrons included seven battle ships of the first class, nine of the second, and three of the third; three armored cruisers, eleven cruisers of the second class, and seven of the third class; five torpedo vessels and twenty-four first-class torpedo boats; sixty-nine pennants in all. Of the torpedo boats No. 81 is a White boat, and Nos. 64, 66, 67, 72, 76, 78, 79, and 80 are Yarrows; the remainder are Thorneycrofts. Each boat carried four torpedoes, and Nos. 80 and 81 carried rapid-fire guns.

Of the 432 heavy guns carried by the battle ships and cruisers, 262 were breech loaders of modern patterns varying in size from 25 hundred-weight to 110 tons; and the remainder were muzzle-loaders varying in size from the 64-pounder to the 80-ton guns of the *Inflexible.* The secondary batteries footed up a total of 218 rapid-fire guns and 407 machine-guns; and the number of torpedo-ejecting apparatus, apart from those of the torpedo-boats, was 168. Every ship in both squadrons was supplied with automobile torpedoes.

The estimated sea speed of the armored ships was from 10 knots to 15.7; of the cruisers from 11.9 to 17.3; and of the torpedo-boats from 16 to 21.5. The failure to realize and maintain the speed at which the vessels were rated was one of the most disappointing features of the manœuvres.

All ships classed together were considered to be of equal strength; *i. e.*, an armored ship was considered equal to any other armored ship, a protected cruiser to any other protected cruiser, and an unprotected cruiser to any other unprotected cruiser. This did not apply to the strength of cruisers and torpedo vessels, as classified above, while engaged in attacking and defending commerce.

The interval between the 7th and 16th of July was employed by the squadrons at Portsmouth and Portland in shaking down and exercising, in preparation for the work ahead of them. The rigging out of torpedo-defense nets by the A squadron at Portsmouth proved a long and tedious task. The signal was made at 9.30 a. m. and it was well on to 6 p. m. before all the ships had finished; and no ship made better time than six hours. A correspondent says that the arrangements for getting the booms and nets in and out appears to lack originality and to be about the clumsiest that could be devised; and he adds that fitting defense nets at sea, unless in the very finest weather and smoothest water, would be with present equipment an impossibility. It was not stated what the condition and position of booms and nets were at the beginning of the evolution; but the inference is that they were in that state of readiness in which they would be habitually carried on a blockading station. The chief defect seems to have been due to the weakness of the wooden booms, which are still used. In three ships the heads of these were wrung off.

The *Collingwood's* full-charge firing trials at Spithead after commissioning were conducted by picked men from the *Excellent*, and even with these trained crews there were some trivial accidents to the mechanism of the guns. Occasions of this kind seldom fail to demonstrate the necessity of keeping men and officers in constant familiarity with the ships and guns which they are to handle in time of war. Broad Arrow of July 14 said:

> The weak part of the mobilization scheme will most likely prove to be its inability to apportion to the different ships crews acquainted with their several peculiarities. The nucleus on board of each ship in the Reserve is neither large enough nor sufficiently inclusive to leaven the whole.

The value of the mobilization as a test of the readiness of the navy for war has been much questioned. It was quietly and expeditiously effected, the programme was carried out with very few delays and obstacles; but the ships that were to be commissioned had been known at the dock-yards since March, every possible preparation had been made, the country, the press, and the navy had been talking of the intended exercises for months. It would be idle to assume that there was any element of suprise in the matter or that the order to mobilize found the British navy in its normal condition. The Morning Post of July 4 said of the six ships commissioned at Portsmouth, "that for more than a month the steam reserve had been engaged in fitting them out for their crews." They had been fully provisioned, armed, and equipped. The men had been drafted and each had received a card showing his station and duties. Upon marching them on board there was really nothing to do but stow hammocks and get up steam. Some of the ships might have gone to sea within forty-eight hours. The *Collingwood* had coal and three months' stores on board. With the exception of taking in powder and live shell she was in all respects ready for sea when her pennant was broken at 8 a. m. July 4. The *Mersey*, at Sheerness, had everything on board except provisions, powder, shell, and gun-cotton.

She was commissioned at 9 a. m. July 4, swung ship, had full-speed trial, and at 2.50 p. m., July 7, sailed for Spithead.

Broad Arrow said that "the vessels were collected very expeditiously and reached their rendezvous in a state of preparedness for service which reflected the highest credit upon the admiralty and dock-yard officials." This optimistic view was largely echoed by the daily papers and was cheerfully accepted by the admiralty officials. It was admitted that there had been plenty of warning, but it was asserted that the same warning would not be wanting in the event of actual service; that war always gave notice in advance; and that before the quarrel had passed out of the hands of diplomacy there would be ample time to make the same preparation. This may or may not be true. It depends entirely upon the circumstances of each case. The argument is unsound, and its fallacies are dangerous. At the best, such an experience is a "war panic," with waste, confusion, and extravagance; and recent history has proved that "war panics" are more expensive than the maintenance of a service in a state of readiness and efficiency.

The weight of professional opinion condemned the mobilization as misleading. As a means of providing a large fleet for the excellent and valuable manœuvres which followed, it was very well; but as a test of the navy's readiness for war it was a deception. The mobilization of the reserve personnel must always be a very important part of a general scheme. This has never been done in England; and in any country depending upon volunteer reserves this feature is sure to be attended by difficulties which practice alone can fully develop. Only a few of the Coast guard were called out in July; and, as the Army and Navy Gazette very appropriately remarked, "no serious hitch in mobilization should have been expected while it was in the power of the Government to limit the number of ships commissioned to that for which officers, seamen, and stokers were available."

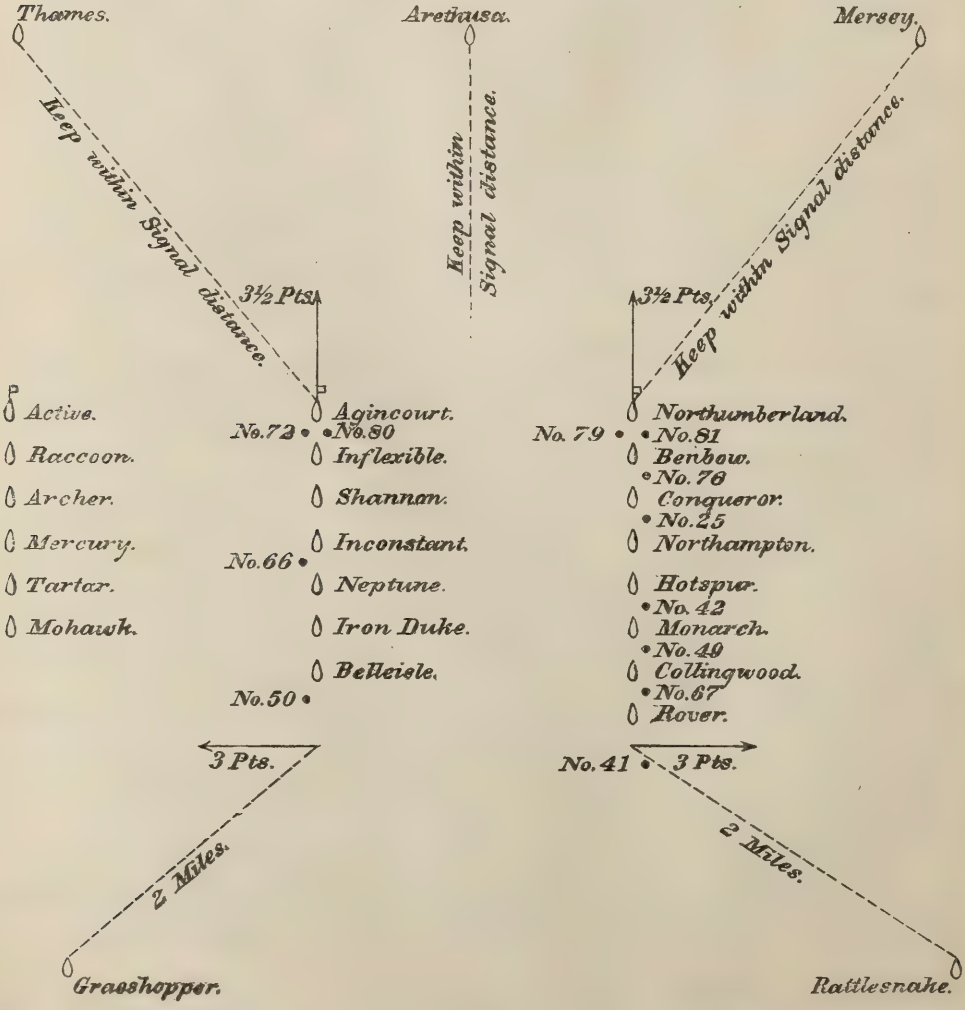
The magnificent fleets which lay at Spithead and Portland on July 7, assembled nominally on five days' notice, represented, not five days' preparation for war, but the best efforts of the dock-yard authorities for several weeks. But this does not take away from the professional importance of the operation, its lessons to officers and men, and its ultimate value to the country. The excellent training of the active personnel of the navy and its admirable discipline and *morale* were shown in a gratifying manner. Whatever may have been the time spent in the preparation of the ships, the fact remains that when officers and men had been three days together in them they were all ready for service. The experience is enormously valuable, and probably the same mobilization could be more effectively performed another year in half the time.

A deficiency noted at the dock-yards was the lack of wharf room where ships can lie when commissioning. The old plan of hoisting the pennant in the stream is clumsy and slow, and must go to the rear with other cherished traditions of a former time. A few deficiencies in outfit were reported. The *Mersey* sailed with only half her torpedo supply, the missing ones including those for the submerged tube, which was thereby rendered useless. The *Severn* was unable to get any torpedoes before leaving the outfitting yard. The *Rodney* was supplied with primer tubes for M. L. instead of B. L. guns, and would have been unable to fire her guns had the mistake not been discovered in time and corrected.

THE MANŒUVRES.

"A" squadron sailed from Spithead with sealed orders at 10 a. m. on Monday, July 16. The *Inflexible* had trouble with her anchors, and the admiral, after waiting some time, sailed without her. She joined the flag on the morning of the 17th. One of the *Thames's* engines was temporarily disabled, but she repaired it while under way. After passing the Nab light-ship at about noon the squadron formed in the following order, rounded the Isle of Wight, and proceeded to the westward at a speed of 10 to 11 knots. The torpedo boats exercised as a flotilla between the lines, under the direction of Lieutenant Jackson, the flag-

CRUISING ORDER OF A SQUADRON.



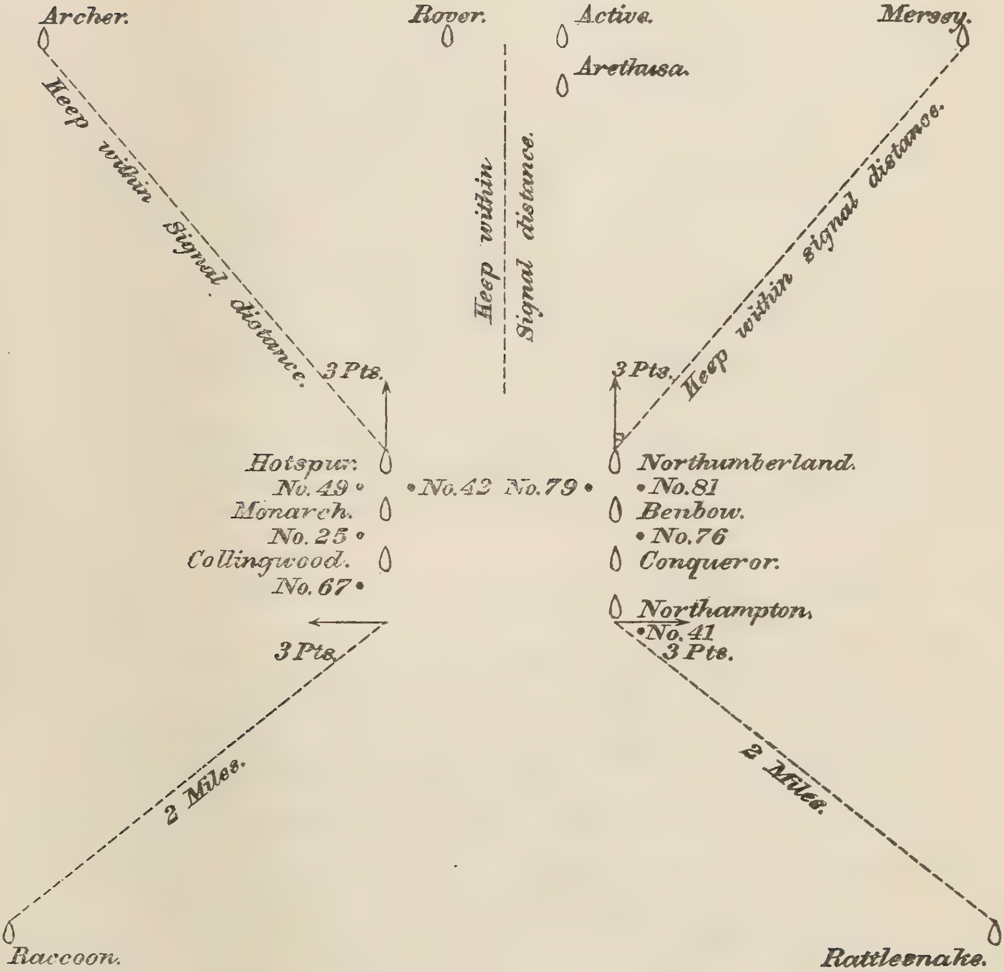
officer of the flotilla, and then joined their respective ships off St. Catherine's Point. All day the squadron was engaged in evolutions and drills, including repelling torpedo attack.

The *Nessmore*, a steam collier, accompanied the squadron.

At 5.30 p. m. the second division was detached and sheered off to the southward, and from that time acted independently, although it remained in sight until noon of the next day.

The first division assumed the following order:

CRUISING ORDER OF FIRST DIVISION, A SQUADRON.



At 8 p. m. the advance ships were off Portland, and speed was diminished to 6 knots per hour.

Early in the morning of the 17th the squadron passed Plymouth. The torpedo-boats under convoy of the *Raccoon* were sent in to Falmouth for water and coal. At 10 a. m. the Lizard was sighted, and soon afterwards the *Volage* and *Sandfly* were seen inshore with six torpedo-boats of B squadron. The *Volage* had torpedo-boat No. 64, apparently disabled, in tow. The *Sandfly*, with the other five boats, made off to the westward. Admiral Baird signaled the *Arethusa* to chase them 50 miles beyond the Scilly Islands to ascertain if they were bound for an Irish port or trying to slip into an English one. After performing this service, the *Arethusa* was to go at once to Milford Haven. The *Mohawk* was detached to watch the *Volage*.

The division cleared for action and exercised in steam tactics, the sea being very rough.

The *Arethusa* got steam on all her boilers, and making 15 knots, quickly overtook the *Sandfly* and the five torpedo-boats, which were unable to go more than 10 or 12 against the fresh breeze and heavy sea. Even at that speed the sea broke almost continuously over them. The torpedo-boats were Nos. 53, 54, 59, 60, and 78. Had war been then declared they would all, with the *Sandfly* and *Volage*, have been captured by Admiral Baird's squadron. The *Arethusa*, having ascertained that they were bound for Bantry Bay, rejoined her flag.

At 6 p. m. the *Northampton's* steering apparatus broke down and she became quite unmanageable, sheering to port out of line. The torpedo-boats proceeded from Falmouth to Milford Haven, and were joined there at 8 a. m., July 18, by the first division of A squadron. They made heavy weather in getting around the Land's End, and No. 41, reported defective, was sent to Pembroke for repairs. Each torpedo boat was assigned to a "parent ship" in the squadron, to which she looked for water, coal, provisions, and assistance, if necessary.

The *Agincourt*, flag-ship of second division, A squadron, collided with the steamer *Sestos* off Falmouth on the morning of the 17th, and had a marine killed. The division reached Lamlash Bay at 4 p. m., July 18. The *Mercury* had been sent on ahead with torpedo-boats Nos. 50, 66, and 72, and No. 80 joined on the 21st. The division completed with coal, taking in 2,000 tons. Two colliers which arrived on the 21st were taken up on time charter. Bad weather was encountered on the passage from Spithead, and the *Inflexible* had four men washed overboard and one of them drowned. The *Belleisle's* steering-gear broke down.

The two divisions of A squadron at Milford Haven and Lamlash Bay completed with coal and provisions. Some delay resulted from deficiency in the supply arrangements. Before leaving Spithead the admiral was furnished with a list of colliers to be expected at Milford, and these were told off to the several ships of the fleet according to their requirements. Upon arrival at Milford a different list was furnished, and new arrangements, involving some delay, had to be made for distribution. Furthermore, some of the colliers were late in arriving. The weather was bad, and coaling in the outer roads was difficult. Two of the *Benbow's* torpedo-booms were carried away by the collier alongside, and she was obliged to shift her berth. Some of the ships were unable to complete their supply before departure for the blockade.

Each ship of the blockading squadron was directed to prepare a special landing party of fifty men to be ready to land at fifteen minutes' notice, fully equipped with arms and provisions for twenty-four hours, in case it should be desirable to rush a signal or telegraph station.

The steam launches of the squadron were painted black to diminish risk of exposure by the electric light, and outfits of provisions and stores for four days were arranged for them.

At 12.30 p. m., July 16, both divisions of B squadron sailed from Portland; the first for Berehaven, Bantry Bay, and the second for Lough Swilly.

The weather was very thick at starting, and the speed was fixed at 5 knots, afterwards increased to 7, and then to 8, which was maintained by the first division all the way to Berehaven, and proved to be the maximum speed of the *Rupert*, a ship rated at 11½.

After getting clear of Portland the torpedo flotilla manœuvred in tactical exercises. While steaming in squadron order in fog, leading ships towed buoys two cables' lengths astern.

At 2 p. m., July 18, the *Hercules*, *Ajax*, *Warspite*, *Rupert*, *Hero*, *Cossack*, and *Iris* arrived at Berehaven. Later the *Severn* came in, having touched at Plymouth for her torpedoes, and the *Sandfly* with torpedo boats 53, 54, 59, 60, and 78, also arrived. The *Oranmore* and two other colliers had preceded the division, and the ships coaled from them. The *Oranmore* then went to Lough Swilly, to supply B^2 squadron. At 4 p. m., July 19, the *Volage* came in with disabled torpedo-boat No. 64. The boat had been nearly lost, and while in tow of the *Volage* had got foul of her quarter and had her bow compartment considerably injured. Other colliers reached Berehaven, and the ships completed coaling on the 20th.

Preparations were at once begun to guard the ships against torpedo-boat attack.

Berehaven, the anchorage of the ships, is the channel which separates Bere Island from the mainland on the northwest. It was supposed to be so heavily and strongly fortified that no hostile ironclad could approach it to within 4,000 yards. The two entrances to the channel were protected by booms and mine fields, and commanded by batteries of rapid-fire guns landed from the squadron. At the west entrance three batteries were placed on shore, viz: on the "Beacon," on "Point Piper," and on "Old Fort Rock." A boom constructed between two Coast-guard vessels was also thrown across. Patrol guard boats were employed, and search lights were always ready for use. At the east entrance there were also three batteries, placed on "Roancarrig Island," on "Point Lonehort" (the Perch battery), and on "Point Carragh," from which latter a boom was extended right across the harbor, in front of which, on either side, mine fields were prepared. The *Rupert*, with her nets out, was moored head and stern in the centre, and entrances 50 fathoms wide, capable of being closed at short notice, were provided on either side of her, which entrances were guarded in the rear by observation mines. Special arrangements in the shape of entanglements, land mines, etc., were provided for the security of the torpedo stations and other establishments on shore.

For the convenience of torpedo-boats a launch was used as a reservoir for water, which was led into it from an adjacent stream by a hose.

Berehaven was connected by telegraph with the signal stations of Brow Head and Cahermore.

Along the whole length of Bere Island runs a chain of hills, the highest 900 feet above the sea. In an old martello tower, on the summit of one of these hills, a signal station was established. Bere Island conceals the anchorage from the mouth of Bantry Bay.

The *Ajax*, *Warspite*, and *Hero* were exercised in getting out the second-class torpedo-boats which they carry, and all the ships of the division got out torpedo nets except the *Iris*, which was not supplied with them. The *Ajax* got out her nets in an hour, being first ship.

Admiral Tryon issued a notice to merchant vessels, warning them that the entrances to Berehaven were obstructed, and directing them what signals to make on approaching and how to enter.

B^2 squadron proceeded to Lough Swilly, arriving there at 4.40 p. m., July 19.

The *Calypso*, convoying the torpedo boats, went on in advance. The *Hearty* joined the squadron en route. The weather on the passage up was bad, and only one torpedo-boat out of six arrived in first rate condition. The *Calypso* had leaky boiler tubes, and the *Serpent* had burst a steam-pipe. The *Oranmore* arrived at noon on the 20th, and on the 22d another collier came in.

Nothing was added to the defenses of the northern port. Admiral FitzRoy's usual plan seems to have been to keep a heavy battle-ship in the entrance, and with his scouts and torpedo boats to keep up communication with the main squadron at anchor in the Lough near Buncrana.

A^1 squadron left Milford Haven in half a gale of wind at 9.30 a. m., July 22d. The *Raccoon* and *Arethusa* remained behind, the former as a dispatch vessel with torpedo boat No. 79 under her orders, and the latter to bring on the torpedo boats when the weather moderated. The *Arethusa*, with Nos. 25, 41, 49, 67, 76, and 81, and the collier *Nessmore* left Pembroke later, and overtook the flag off Kinsale Head at 6 p.m., July 23d, having steamed into a heavy southwest gale and sea all the way across the Irish Channel. The torpedo-boats were constantly swept from bow to stern, but their captains did not wish to slow down below the speed which was comfortable for the ships. Admiral Baird sent the *Arethusa*, *Rattlesnake*, and the torpedo boats into Kinsale harbor for a night's rest, and directed them to join him at 11 a. m. the next day off Mizen Head. A few hours later he sent back the *Archer* to relieve the *Arethusa* at Kinsale, directing the latter to join the flag. The *Archer* with the torpedo boats was directed to search all the harbors from Kinsale to Mizen Head. At 11.30 a. m., July 24th, Baird's cruisers were off

Dunmanus Head, and at noon the blockade of Bantry Bay was established.

At 1.30 p. m., July 23d, A^2 squadron, with the exception of the *Belleisle*, left Lamlash Bay. At 2.50 p. m. the *Mercury*, the *Grasshopper*, and the four torpedo boats were sent ahead with orders to arrive off Lough Swilly early next morning. At 11.45 a. m., July 24th, the squadron reached Lough Swilly, found the *Mercury*, *Grasshopper*, and torpedo-boats in position as ordered, and established the blockade. The *Belleisle* and the collier *Glenmanna* left Lamlash for Lough Swilly on the 24th.

All the ships engaged in the manœuvres were supplied with their "units" (allowances) of ammunition. It took much time to hoist in and stow the heavy charges. The cartridges and shell for the heavy guns of the *Benbow* weigh about 500 tons; and in all ships the relative importance of this factor has vastly increased in twenty years. But facilities for meeting this increased demand in respect to receiving on board and stowing have not received proper attention. The *Collingwood* has only two places for striking down powder and the process is very slow.

The four admirals had been informed by admiralty telegram, dated July 21st, that war would be declared on July 24th at noon, and would last until noon on August 20th. Promptly at the time fixed, hostilities began at both ports.

The plan of blockade at Bantry Bay was as follows: (See map.)

An "inner line of lookouts," consisting of the *Rattlesnake* and torpedo-boats Nos. 25, 41, 49, 67, 76, and 81, under the command of Lieutenant Jackson in No. 81, was to watch both entrances of Berehaven and patrol the channel between Bere Island and the mainland.

The "inner cruising squadron," consisting of the *Active*, *Rover*, *Mersey*, *Archer*, and *Collingwood*, under the command of Commodore Markham in the *Active*, was placed across the mouth of the bay from Sheep's Head to Black Ball Head.

This squadron was subsequently augmented by the *Raccoon* on July 28th, by No. 79 on the 29th, and by the *Arethusa* on the 30th.

The "outer squadron of ironclads," the *Northumberland* (flag), *Benbow*, *Conqueror*, *Monarch*, *Northampton*, and *Hotspur*, was stationed farther out, between Mizen Head and Dursey Head.

The orders for the "inner cruising squadron" were to take up stations at 10 p. m., an interval of 2½ miles between ships; steam kept up for full speed, but not moving; no lights shown; the electric light not to be used if avoidable; one watch to be kept sleeping at the guns. Should an ironclad escape, the *Collingwood* and *Mersey* were to proceed at once, without signal, in chase.

Orders were given that the electric search lights were not to be turned on ships advancing at night, as the effect is more puzzling to the ship using it than to the one upon which its beam is thrown.

Telegraphic centres were established at St. Ann's Head entrance to Milford Haven, and Scilly. The *Raccoon* and No. 79 had been left at Milford Haven. The *Arethusa*, with No. 42, was subsequently stationed at Scilly.

There were inner and outer blockading squadrons or lines of patrol at Lough Swilly. (See map.) Each line made the arc of a circle, having its center midway between Fanad and Dunaff Heads, the radii being about 8 and 12 miles, respectively. Four vessels, with two torpedo-boats on each flank, constituted the inner patrol; and the main body of the squadron, with a flanking scout near the shore on both sides, made up the outer. During the day-time no fixed distance was observed between the ships, and the speed was regulated by circumstances. At nightfall the inner line was closed nearer the entrance.

Lamlash (isle of Arran) and Port Ellen (Islay) were both used as telegraphic stations, but the first was the established base for dispatches and main telegraphic centre.

FitzRoy received intelligence of Rowley's movements from Malin Head, Fanad and Dunaff Heads at the entrance to the Lough, and from Dunree Head midway towards Buncrana, which latter was the telegraphic centre.

Baird's ships coaled from the *Nessmore* and other colliers in Dunmanus Bay, Ballydivlin Bay, and Castle Island Sound, all near Bantry. Rowley's ships coaled at a sheltered bay a few miles to the westward of Lough Swilly, and another near Owensay Island, one or the other being selected to get smooth water, according to the direction of the wind. Port Ellen and Loch-na-Dail, island of Islay, 50 miles distant, were also used as coaling stations.

In order to avoid confusion of time in the narrative, all the principal movements of each day throughout the whole theatre of operations are given under its date. The operations of the detached cruisers preying upon commerce are separately summarized.

Liberal extracts have been taken from the report of the Committee on the Naval Manœuvres, consisting of Admirals Dowell, Hamilton, and Richards, and these are acknowledged by quotation marks.

TUESDAY, *July* 24.

Bantry Bay.—"At noon, the Achill ships *Iris* and *Cossack* being observed cruising to the southward of Roancarrig light-house, the iron-clad division of A^1 squadron proceeded up Bantry Bay to reconnoitre the position, approaching rather closely to Bere Island. Fire was opened on the *Iris* and *Cossack* when at 4,000 yards distance, and was continued for about ten minutes, when they retired. The ironclads stood out again when 2 miles SSE. of Doonbeg Head (Bere Island). At 3 p. m. the ironclads again stood in to 3 miles SW. by W. of Roancarrig. Fire was opened on two torpedo-boats off Lonehort Point.

"A torpedo-boat carrying a rear-admiral's flag was fired at from *Northumberland* and *Mersey.* This incident was not reported by the commander of the Achill squadron.

"The admiral of A^1 squadron claimed to have killed his chief opponent (the Achill admiral) in a torpedo-boat, besides sinking *Iris* and *Cossack.* The Achill admiral claimed to have sunk *Mersey* and *Rattlesnake*, and put *Northumberland* and two other ironclads out of action by heavy guns on Bere Island.

"The *Arethusa* was dispatched after dark to Milford to coal, thence to proceed with No. 42 to Scilly, and take up position there.

"By 9.30 p. m. the ships of A¹ were all in their blockading positions. Between 10 and 11 an alarm of Achill torpedo-boats coming out was raised, but it turned out to be false."

Six torpedo-boats of A¹ squadron which had put into Crookhaven were surprised by the coast guards, and were under fire for several minutes without reply.

The *Collingwood* fired upon 67, a torpedo-boat of A¹ squadron, which approached her for assistance, having burst her feed-pipe.

Lough Swilly.—Shortly after noon B² squadron steamed down towards the mouth of the Lough. The *Calypso*, *Amphion*, and *Curlew*, which had been sent outside in the forenoon to reconnoitre, fell back on the main line. At 2 p. m. the *Amphion* went out some distance, supported by the *Black Prince* and *Hearty*, nearer shore. The *Inflexible* made a dash at her, but without success. At 6 p. m. the *Thames* and *Neptune* chased the *Hearty*, which appeared outside the Heads. The *Amphion* came first to her assistance, and then the whole B² squadron, which moved out in force, and a general action ensued, Rowley's ships moving in to support the *Thames* and *Neptune*. During this fight the *Neptune* was for twenty minutes within range of the supposed batteries on Fanad Head. At 7 p. m. the Achill squadron retired into port, and night stations were taken up by both sides.

FitzRoy left his torpedo-boats during the day at Buncrana; also the *Serpent*, repairing bad breaks in her main and other steam pipes.

The *Hearty* was used as a supply boat to bring mails and fresh provisions from Buncrana.

WEDNESDAY, *July* 25.

Bantry Bay.—Shots were exchanged between the *Rattlesnake* and No. 41, and two of the Achill torpedo-boats, which retired again at 3 a. m. The *Mersey* reported having chased the *Cossack* at 1 a. m. At 5 a. m. commodore signaled, "*Iris* is reported by *Mersey* to have escaped." The *Archer* was instantly sent to Milford to inform Rowley and Coast-guard lookout stations. Two hours later it was discovered that this news was incorrect, a mistake having been made in receiving the signal from *Mersey*. The *Rattlesnake* reported that she had put a torpedo-boat out of action near Roancarrig during the night. At 7 a. m. the *Active* and *Monarch* were sent to Castle Island Sound and Ballydivlin Bay, respectively, to coal from the *Vulture* and *Nessmore*. At 11.20 a. m. B¹ squadron appeared in force at the eastern entrance to Berehaven, and advanced toward the blockading ships, and Baird, fearing an engagement, recalled the *Monarch* and *Active*, which had taken in only a small amount of coal. The *Mersey* made a dash at the *Volage*, which was creeping along under the western shore, and opened with her heavy guns, but was speedily driven off by the *Iris* and *Severn* after some sharp firing. The Achill battle-ships retired, exercised in fleet tactics, and returned to Berehaven about 4 p. m.

"Blockading positions were again taken up by 9.30 p. m., the inner lines being somewhat closer in than on the previous night.

"At 10.30 torpedo-boats of A¹ squadron, with *Rattlesnake*, were engaged with five of the Achill boats. Masted vessels were also reported coming out, on which *Northumberland*, *Benbow*, and *Monarch* moved towards Dursey Head, but as nothing was sighted, returned to their stations. No mention of any ships having moved during the night is made by the Achill admiral."

The *Arethusa* ran 16 knots all night in a heavy sea and reached Milford Haven at 10 a. m., where she coaled. At 9 p. m. the *Archer* came in bringing the news that the *Iris* had broken the blockade.

Lough Swilly.—"At 3 a. m. the *Rodney*, *Black Prince*, and *Invincible* went out to reconnoitre, returning to outer anchorage about 7 a. m.

"The *Belleisle* joined the blockading squadron at 4 a. m., bringing the collier *Glenmanna*, which was taken into Culdaff Bay (a short distance to the eastward of Malin Head). No. 66 was sent to Port Ellen for telegrams at 8.30 a. m., and at 9.15 the *Mohawk* sailed for Lamlash with the mails.

"The *Mercury* reported that at daylight the *Amphion*, a turret ship, and the *Spider* were observed anchored close inside the entrance to the Lough. The *Curlew* was outside in Trawbreaga Bay.

"The night was clear. FitzRoy's ships made no movement. The blockading squadron patrolled as on previous night."

The *Mohawk* reached Lamlash at 8.30 p. m., No. 66 reached Port Ellen at 2 p. m., and left without delay.

THURSDAY, *July* 26.

Bantry Bay.—"At 7.15 a. m. the Achill squadron again weighed and stood out of harbor; it returned again about 11 a. m., and the ships hauled fires.

"No. 67 torpedo-boat despatched to Milford with directions for *Raccoon* and No. 79 to rejoin A^1 Squadron.

"*Volage* came out of harbor in afternoon; was chased by *Rover*, supported by *Mersey*, which ships had her within effective range for a short time; on *Volage* making for the harbor and getting under cover of *Rupert's* guns (in east entrance), A^1's cruisers retired.

"The blockade was again closely established in the evening, but no movement of Achill vessels or boats was made during the night."

The *Rover* claimed that in the afternoon's skirmish she had got near enough to the *Volage* to ram her. The *Monarch* coaled from the *Nessmore* at sea, using boats.

At 5.50 a. m. the *Arethusa* left Milford Haven to cruise in search of the *Iris*, and No. 42 to take up station at Scilly.

Lough Swilly.—At 6 a. m. the *Thames* was sent in to endeavor to cut out the *Curlew*, she being in Trawbreaga Bay (outside the Lough), the blockading squadron moving up to support. The *Curlew* was soon assisted by the *Amphion* and *Calypso*. Firing commenced at 7.20 and lasted about twenty-five minutes, during which time the three Achill vessels were subjected to a heavy fire, but the *Thames* and *Mercury* were exposed for seventeen minutes to the fire of the supposed "38-ton guns on Dunaff Head."

At 11 a. m. the Achill admiral with his whole force of four ironclads, flanked by the *Amphion* and *Calypso*, stood out to engage the British squadron, which was temporarily weakened by the absence of the *Neptune*, *Iron Duke*, and *Shannon*, which, with the cruisers, were on scout duty.

"A short action took place between *Rodney* and *Devastation* of Achill, and *Agincourt*, *Inflexible*, and *Belleisle* of British fleet, which latter were soon supported by the outlying vessels. The Achill squadron retreated towards the Lough, followed by ironclads of A^2, and entered it about 1 p. m., when the British ships resumed their positions.

"At 2 p. m. *Mohawk* returned from Lamlash bringing the news (which subsequently turned out to be unfounded) of escape of *Iris* from Berehaven. She reported Coastguards of the Isle of Arran on the alert.

"At 5 p. m. Achill squadron moved up to their inner anchorage, leaving *Invincible* with nets out, on guard at the entrance.

"The night was light, with moon, and passed quietly, except for a false alarm raised by *Thames*."

The *Serpent* completed her repairs.

FRIDAY, *July* 27.

Bantry Bay.—Rain and thick fog in the morning. The "inner cruising squadron" of the blockaders was still further reduced by the absence of the *Mersey* repairing her steering gear, which had broken down. The *Archer* returned in the afternoon.

"At 4 a. m. *Volage* went out of harbor and returned 8.30. At 1.30 p. m. A^1 ironclad squadron, with *Archer* and *Rattlesnake*, made a reconnaissance at full speed;

Rattlesnake sent in towards Roancarrig, and on fire being opened on her by *Rupert*, she retired.

"Four Achill torpedo-boats, Nos. 53, 60, 64, and 78, went out at 8.30 p. m., followed by *Sandfly* at 10.30; the former were engaged by the blockading boats Nos. 81 and 49 at long range, and the latter by *Rattlesnake*, shortly before midnight.

"The collier *Vulture* (attached to A squadron) was captured by Crookhaven Coast-guard and taken to Schull.

"Achill boats, with *Sandfly*, returned into harbor about 1 a. m."

The night was fine. An alarm was created by the *Rattlesnake*, which came out from her station at full speed and reported that she had been chased by a cruiser. No. 67 reached Milford at 4 a. m., and *Raccoon* and No. 79 left Milford at 8.50 for Bantry Bay.

Lough Swilly.—The *Hearty*, *Spider*, and six torpedo-boats of FitzRoy's squadron came in to Buncrana at 5 a. m., after cruising off the entrance of the Lough during the night. The main part of the squadron lay at Buncrana all day, three cruisers being in station just outside the Heads, and the *Invincible* anchored half-way between, to repeat signals.

"Achill admiral sent to general commanding district a request for artillery and infantry to be sent to Culdaff Bay, Sheep's Haven and Innisboffin, for the purpose of preventing British squadron from coaling there; marines of *Black Prince* landed to assist the military in this object.

"At 8 p. m., the weather being thick, *Spider*, and No. 45, were sent out to endeavor to torpedo two of the British ships. *Spider* claimed to have been successful, and to have sunk *Inconstant*.

"On account of the thick weather the blockading squadron were, for the safety of passing vessels, compelled to carry their bow and stern lights.

"A considerable amount of desultory firing at real and imaginary torpedo-boats occurred during the night. One of the Achill cruisers fired upon one of her own torpedo-boats which came back unexpectedly into the Lough to make a slight repair in her machinery, and failed to give the private signal when challenged. The electric light was used and several other ships took up the firing."

SATURDAY, *July* 28.

Bantry Bay.—The *Raccoon* arrived from Milford with mails at 10 a. m. She had parted company with No. 79.

"Armed party from *Archer*, including marines from the flag-ship, sent to capture telegraph station on Brow Head; this was effected, Crookhaven Coast-guard station having first been reduced. Three Coast-guardsmen and two telegraphists were brought off as prisoners. Achill admiral claimed that the capture could not have been effected under the circumstances and with the force used (forty marines and party of blue jackets) in actual warfare.

"At about 4 p. m. *Volage* came out under a flag of truce, bringing demand from Achill admiral for Nos. 81 and 49 to be given up, as they were put "out of action" during the skirmish of the previous night. This request was not complied with, and counter-claims were made by British admiral.

"The collier *Vulture* was recaptured in Schull harbor."

The *Rattlesnake's* boats while getting water from the shore in Horse Island channel near Schull, were attacked by the Irish Coast-guards and had a sharp fight with them.

"No movement on the part of the Achill vessels or boats during the night."

Lough Swilly.—"Weather wet and cold. As *Amphion* and *Serpent* were not at their accustomed places off the Lough, the British admiral sent *Thames* to Lamlash at 8 a. m. to endeavor to find out if they had escaped.

"At 9 a. m. *Amphion* and *Serpent* appeared, and *Tartar* was sent to Port Ellen to acquaint *Thames* by telegraph.

"At 6.15 p. m. fire was opened on *Amphion*, which was some distance outside the harbor, by *Agincourt*, and *Spider* was fired at by *Inconstant;* they were within range for thirty minutes.

"7 p. m. *Tartar* rejoined A^2 squadron; weather was thick again during the night, and no movement of importance was reported on either side."

The *Thames* reached Lamlash at 4.30 p. m. and coaled.

SUNDAY, *July* 29.

Bantry Bay.—"Weather foggy and showery. A reconnaissance was made by No. 81 of eastern entrance at dawn; she was fired and chased by an Achill boat, but successfully regained her flotilla."

The *Archer* returned with her prisoners and was sent away at once to meet and convoy the *Alliance*, a collier that was expected. She returned at noon with the collier, from which the *Collingwood* coaled. The *Hotspur* coaled in Dunmanus Bay from the *Nessmore.*

The *Active* captured the *Argus*, a collier coming out of Bantry Bay, and obtained information from her respecting Tryon's mines and booms. She reported that the ships in Berehaven showed no signs of moving.

"*Vulture* sent to Scilly with orders for *Arethusa* to rejoin A^1 squadron, leaving No. 42 at the base.

"At 5 p. m. No. 79, from Milford, rejoined the blockading squadron; she reported that she had been chased off the Smalls by three vessels. (No. 67 had also reported being chased by two men-of-war on the 26th July in the same locality.)

"At 3.30 p. m. A^1 squadron stood in towards Roancarrig. *Benbow* was detached and sent in under flag of truce. *Sandfly* sent out to meet her, also under flag of truce. After communicating, both vessels returned to their respective squadrons.

"No movement on the part of the blockaded squadron during the night."

No. 79 thought that one of the ships which had chased her was the *Amphion*, and that they were all FitzRoy's cruisers escaped from Lough Swilly.

Lough Swilly.—The *Thames* left Lamlash at 2.40 a. m. with dispatches, to join A^2 squadron.

"At 10 a. m. *Rodney*, without the admiral's flag, appeared outside and steamed rapidly first to the eastward, then turned to westward. *Inflexible* detached to watch her movements. *Rodney* opened fire on *Inflexible* at 10.15, and within five minutes *Agincourt* and *Belleisle* joined in the action; shortly afterwards *Neptune* moved up and Joined in also. B^2's cruisers were also under fire during part of the time. The engagement ended at 10.50, and *Rodney* returned into port. *Thames* returned from Lamlash.

"At 12.30 *Curlew* came out under flag of truce, bringing out umpire. A conference took place between umpires of both sides to decide the claim for *Inconstant*, torpedoed by *Spider.*

"The umpires decided that *Spider*, being classed as a cruiser, could not, by the rules, come within 1,000 yards of a battle-ship or use her torpedo. Claim, therefore, was disallowed."

In the afternoon the *Mercury* went to Loch-na-Dail to coal. The *Tartar* was sent to Lamlash for the same purpose.

"During the night, which was fairly clear, all was quiet."

MONDAY, *July* 30.

Bantry Bay.—The *Collingwood* and *Northumberland* went into Dunmanus Bay to coal, and Admiral Baird hoisted his flag for the day in the *Mersey.* At daylight the *Rover* was sent off Mizen Head, and the *Raccoon* off Dursey Head, to look out for the enemy's cruisers, supposed to have escaped (those reported as having chased No. 79), with orders to rejoin the squadron in time for blockading at night.

"Nos. 81 and 79 reconnoitered the eastern entrance just after daybreak, but had to retire from the fire of ships, forts, and boats.

"3 p. m. *Volage* sent out with flag of truce and met by *Hotspur;* dispatches were exchanged with reference to claims and counter-claims.

"5 p. m. No. 53 (Achill) sent out with flag of truce. All returned whence they came.

"8 p. m. *Northumberland* rejoined A squadron and rehoisted flag.

"Usual patrolling by the blockading fleet during the night, but not a move on the part of the blockaded."

The blockaded admiral was reported to have laid down more mines and strengthened his light shore batteries, and to be much concerned lest the enemy should have captured his private signal code when the signal stations were raided.

The *Arethusa*, which had been cruising after the *Iris*, touched at Falmouth just after midnight, and learned for the first time that the *Iris* had not been outside of Bantry Bay. She found a telegram from No. 42 at Scilly, stating that dispatches from the admiral awaited her there. At 7 a. m. she got under way, reached Scilly at 1 p. m., and sailed at once to join the flag at Bantry

Lough Swilly.—"About 6.45 a. m. *Devastation* came out and stood to the westward; *Neptune* and *Belleisle* were sent to chase her. She was apparently so closely pressed, while retiring toward the Lough, that a claim was made for her as 'out of action.' She returned to her port about 8.30 a. m." The claim was subsequently disallowed by the umpires.

"British admiral shifted his flag to *Inflexible* for the day, sending *Agincourt* to coal" in Sheephaven Bay (to the westward of Lough Swilly) with two torpedo-boats and the collier, and the *Mercury* to watch outside.

"At 11 p. m. Achill torpedo-boats Nos. 52, 55, and 57 were dispatched to make independent attacks on the British squadron. *Inflexible*, *Iron Duke*, and *Thames* were each attacked, but not hit; the boats, however, were so long under fire that British admiral claimed them as destroyed."

They got within firing distance of the ironclads without being seen, although the night was not very dark and the *Neptune* was using her electric light. The missing of the torpedoes, at least in one instance, was due to the inexperience and lack of training of the crews.

The *Grasshopper* and *Inconstant* captured a collier trying to reach FitzRoy's squadron.

The smoke-pipes of the Achill ships were painted black. At 10.30 p. m. the Achill ironclads fired upon one of their own second-class torpedo-boats, which failed to answer when challenged.

The *Serpent's* machinery again failed, and she retired to Buncrana for repairs.

Tuesday, *July* 31.

Bantry Bay.—"At 1.30 a. m. Nos. 49 and 81 (British) came in collision; the bow of the former was stove in. She was dispatched to Milford next night for repairs, and to relieve No. 67.

"*Volage* went out at 7 a. m., with dispatches, under flag of truce.

"*Arethusa* arrived from Scilly and was sent to augment the inner cruising squadron.

"A squadron's cruisers on lookout duty off Mizen Head and Dursey Head.

"An armistice proposed by the British admiral was agreed to by the Achill commander to last from noon to sunset the following day.

"Blockade closely maintained after dark.

"At 10 p. m. *Sandfly* and three (?) torpedo-boats were sent out. *Rattlesnake* engaged the former, and Nos. 41 and 79 reported having cut off one of the Achill boats and claimed her capture. *Active* claimed to have put No. 78 out of action during the night, and that she fired her torpedo afterwards, instead of surrendering as ordered.

"All the Achill boats were in harbor again by 2 a. m. The night was dark and misty."

No. 78 fired her torpedo at the *Active* at close quarters, and picked it up immediately with the copper head crushed in, thus proving a hit beyond a doubt. Positive assertions were made on both sides as to whether or not the *Active* had No. 78 under fire three minutes before she fired her torpedo. Claims were made by both sides but no decision was reached.

Upon returning to Berehaven No. 78 was fired upon by the *Rupert* and the shore batteries at such close range that she would certainly have been destroyed had projectiles been used. Her private signal was either not hoisted, or was not understood.

The *Northumberland* and *Mersey* filled up with coal during the day.

Lough Swilly.—" No active operations undertaken during day or night.

" *Mercury,* with umpire on board, sent to communicate under flag of truce. Owing to a misunderstanding, however, the umpires did not meet.

" At 9 p. m. *Spider* and torpedo-boats were sent out, but attempted no attack."

The *Mohawk* was sent to Lamlash and arrived there at 4.45 p. m.

WEDNESDAY, *August* 1.

Bantry Bay.—The *Rattlesnake* reported that she had been chased out in the night by two Achill cruisers. The *Arethusa, Raccoon,* and *Archer* were sent to cruise off Mizen and Dursey Heads. A boat's crew from the *Arethusa* was captured by the Irish Coast guards.

" *Volage* sent out at 11.30 a. m. under flag of truce, having umpire of Achill squadron on board to confer with A^1's umpire on board *Conqueror.*

" Armistice from noon to sunset. *Volage* returned at 7 p. m.

" Patrols were resumed and blockade established about 8 p. m.

" At 9.30 the Achill torpedo-boats and *Sandfly* were sent out, and an engagement took place between them and A^1's boats with *Rattlesnake.*

" Between midnight and 1 a. m. Achill boats and *Sandfly* returned into harbor.

" The admiralty telegram, ordering ships to proceed to their respective ports and stations on the cessation of hostilities, arrived. This telegram was sent out at 10 a. m. (Thursday) in *Cossack,* under a flag of truce."

The umpires awarded to the Achill admiral two British torpedo-boats put out of action by the fire of the *Collingwood* and *Rattlesnake* (British ships) on the night of July 24–25.

Lough Swilly.—" The Achill cruisers were off the Lough at daylight as usual. *Mohawk* rejoined the blockading squadron from Lamlash at 1 p. m. *Curlew,* under flag of truce, took Achill umpire out to confer with his opposite number in British fleet on the claims for *Devastation,* and Nos. 52, 55, and 57, engaged in the attack of Monday night.

" No engagements or torpedo-boat actions reported. *Agincourt* fired for a few minutes about midnight at what was supposed to be a torpedo-boat."

The umpires decided the claim for the *Devastation* inadmissible, and did not agree as to the torpedo-boats.

THURSDAY, *August* 2.

Bantry Bay.—The *Monarch* and *Archer* went to Dunmanus Bay to coal. The *Raccoon* and *Arethusa* were sent to cruise off Mizen and Dursey Heads.

" The boats of A^1 were re-enforced by second-class boats of *Benbow, Northampton,* and *Hotspur,* and No. 67 from Milford. It was found necessary to give the first-class boats a night off duty in turn to rest, as their crews were becoming exhausted.

" The patrols were established as usual after dark, but no movement was made by any of Achill squadron.

" NOTE.—It should here be remarked that up to this time the Achill admirals had not been free agents, as ' with a view to give sufficient time to gain information and experience of the ability of a blockading fleet to carry out the operations assigned to it,' the admiral in command of each division of B squadron had been acting under the following *secret order,* the existence of which their adversaries were unaware of:

> "*From the date authorized for the commencement of hostilities, it is open to you to harass your enemy day and night by every means in your power; but* NO SHIP OR TORPEDO-BOAT UNDER YOUR ORDERS IS ON ANY ACCOUNT TO ESCAPE *from* $\left\{\begin{matrix}\textit{Berehaven}\\ \textit{Lough Swilly}\end{matrix}\right\}$ *until you receive further telegraphic orders from the Admiralty giving you full freedom of action.*

"These orders ceased to operate on 3rd August."

Lough Swilly.—"5 a. m. No. 66 rejoined the British squadron from Port Ellen after a three days' absence.

"The Achill admiral took his whole squadron out to the entrance of the Lough in the forenoon, and manœuvred for a short time, but did not attempt to engage his enemy.

"Admiralty telegrams were received for the vessels to return to their ports after cessation of hostilities. The one for rear-admiral second in command of A squadron was sent out to him in *Curlew* under flag of truce.

"7 p. m. *Mohawk* was dispatched to Lamlash for repairs to her boilers.

"Achill torpedo-boats and *Spider*, under orders of *Calypso*, went out about 10 p. m.; *Calypso* almost at once proceeded to the eastward, and passing inside Inishtrahull, broke the blockade unobserved; in fact, the circumstance, though suspected, was not definitely known by the British admiral until the morning of the 4th."

The *Spider* and the torpedo boats might have run the blockade with equal ease, but the cruiser returned to the Lough, and the torpedo boats attacked the *Neptune* and *Inconstant*.

FRIDAY, *August* 3.

Bantry Bay.—The *Active* coaled in Dunmanus Bay. There were signs which indicated that the Achill ships intended to make an effort to escape, and an order was given to paint a broad white stripe on each side of the funnels of the blockading ships, to distinguish them from the enemy's. The evening was dull and misty.

"The *Cossack* was sent out under a flag of truce and returned in the evening.

"The patrols were established by A¹ squadron as usual.

"About 10 p. m. the *Warspite, Iris*, and *Severn* preceded by the Achill torpedo flotilla and followed by the *Volage* and *Cossack*, passed out of the W. entrance, the *Hercules, Ajax, Hero*, and *Sandfly* almost simultaneously going out to the eastward. At this time the *Archer* occupied the position nearest to the north shore, under Black Ball Head. Her attention was soon taken up by an attack on her by three or four Achill boats at once, and whilst so engaged the three ships first mentioned, viz, the *Warspite, Iris*, and *Severn*, passed her unobserved, steaming at full speed close in to the high northern land and showing no lights. They had been previously signaled by the torpedo boats of A¹ squadron as endeavoring to escape.

"The *Volage* and *Cossack* steamed at the same time 2 miles to the southward, and commenced firing heavy guns and Very's signals and working electric lights, keeping the beams clear of the three ships which were escaping. The ironclads which came out of the eastern entrance did the same. The Very's signals were fired to confuse those which the *Rattlesnake* and torpedo boats might make.

"The remainder of the Achill squadron and the boats returned into harbor at 1 a. m."

It was claimed by No. 76 that she successfully torpedoed the *Hercules* at the eastern entrance. The claim was probably well founded, but it does not appear to have been decided. The *Archer* was put out of action by the Achill boats, but A¹'s umpire gave no decision before the close of hostilities, and the *Archer* continued her existence as a British cruiser.

A difference of opinion existed as to the good faith of the operations of the night of August 3, at Bantry Bay. Some believed the breaking of the blockade to have been no farce, and some that there was an understanding between the two admirals. Certainly in the face of the secret instructions, which kept Tryon and FitzRoy in port ten days, there is no reason for refusing to believe that the escape was arranged. The stations of Baird's ironclads at the time do not officially appear. It is asserted that they were several miles out to sea, and carried their steaming lights. The cruisers of the "Inner squadron" failed to see the escaping vessels, but if one or two ironclads had been off Dursey Head the chances of detection would have been doubled.

Fortunately the truth of the matter is not material to the value of the conclusions to be drawn from the manœuvres. The question of effective blockade had been pretty well settled before the escape of the Achill ships. It is next to certain that either Tryon or FitzRoy could have sent out fast cruisers any dark night.

Lough Swilly.—"No. 51's attack made on *Neptune* at 1.30 a.m. was unsuccessful, and her torpedo was lost; she was claimed as out of action by *Neptune's* fire. No. 58, however, was successful in torpedoing *Inconstant.*

"Achill umpire sent out in *Curlew* to consult his colleague as to claim for *Inconstant* torpedoed. This claim was subsequently established.

"At 11 a.m. *Thames* was ordered to close in and watch the entrance till weather cleared."

At 5.30 p.m. A^2's torpedo-boat No. 50 captured at Port Ellen by the *Calypso* steamed through the blockading squadron and entered the Lough where she was recommissioned by the Achill admiral as No. 90. She employed a flag of truce to run the blockade into the Lough, and Admiral Rowley informed Admiral FitzRoy that no further flag of truce would be respected until she was given up.

"Some torpedo-boats were observed and fired at by ships of A^2 squadron during the night, which was very dark, but no torpedoes were seen to be discharged."

SATURDAY, *August* 4.

Bantry Bay.—At daylight Lieutenant Jackson, in command of the torpedo flotilla, reported that the *Warspite, Severn, Iris,* andtwo other ships had escaped. Every ship of the inner line signaled that the enemy had not passed out. But Admiral Baird decided, without even making a reconnaissance, to raise the blockade, and at once to support his second in command at Lough Swilly, lest he be caught between two squadrons and captured. At 4 a.m. the *Mersey* was sent full speed by the west coast of Ireland to inform Rowley of Tryon's escape, and to order him to raise the blockade of Lough Swilly and join the vice-admiral off Drummore, Luce Bay, Mull of Galloway, about 120 miles from Lough Swilly. At 5 a.m. the *Benbow, Collingwood,* and *Rover* were sent by the eastern route to meet and re-enforce Rowley. They were directed to first steer for Scilly until out of sight, and then shape course for Lough Swilly, keeping clear of the Irish coast on the way up to avoid being signaled by the Coast guard.

No. 79 was sent to Milford to telegraph Rowley's base and inform the British coast. The *Arethusa* and *Rattlesnake* were left at Bantry to watch the Achill ships still in harbor, and the remainder of the squadron with Nos. 25, 41, 67, 76, 81, and the *Nessmore* sailed at 6 a.m. for Drummore, first standing to the southward until out of sight of the Heads. Nos. 49 and 42 were kept at Milford and Scilly respectively. The *Hotspur* was sent to Milford to coal.

The *Warspite, Iris,* and *Severn* were steaming up the west coast of Ireland to join FitzRoy at a preconcerted rendezvous 20 miles northeast of St. Kilda, one of the Hebrides.

Lough Swilly.—"*Inconstant,* which had been sent to Port Ellen on the previous day, returned at 11.30 a.m. and reported capture of No. 50 by boats of *Calypso. Inconstant* was again sent off to Lamlash with mails and telegrams.

"At 9.30 p.m. the Achill admiral, in *Rodney,* with *Amphion* and *Spider,* ran the blockade at full speed. They were observed at 11.15, and chased by *Mercury* for some distance, but were lost sight of an hour afterwards. Nos. 45 and 58 had been sent out to torpedo one of the British ironclads and cause a diversion by throwing up rockets, burning Very's lights, etc., just before the ships escaped. The British admiral knew nothing of what had happened till next morning. Admiral FitzRoy, as a *ruse de guerre,* left his flag flying on the *Black Prince* at Lough Swilly. When clear of the blockading squadron he detached the *Amphion* and *Spider* to execute orders previously given them, and proceeded alone in the *Rodney* to the rendezvous off St. Kilda. No. 45 torpedoed the *Tartar,* but the claim was never settled."

SUNDAY, *August* 5.

Bantry Bay.—At 5 a. m. the *Rattlesnake* came in close to the east entrance, and fire was opened upon her by the *Rupert* and the Roancarrig and Perch batteries. After reconnoitring, the *Rattlesnake* steamed to the southward at full speed and proceeded to Milford, leaving the *Arethusa* alone at Bantry. At 10 p. m. the *Cossack*, *Sandfly*, and the six torpedo-boats of B^1 squadron were sent out by west entrance to attack the *Arethusa*, and Admiral Tryon, with the *Hercules*, *Ajax*, and *Hero*, put to sea from the east entrance. The three ironclads steamed slowly up the west coast of Ireland, and were joined next morning by the *Cossack*.

This left the *Rupert*, *Volage*, *Sandfly*, and six torpedo-boats in Berehaven. The *Arethusa* was torpedoed by No. 60, and her captain admitted having been struck, but the claim was never acted upon, and she continued to act with A squadron.

Lough Swilly.—At 4 a. m. the *Mersey* arrived, and was immediately sent to warn the *Iron Duke* (which was coaling) and to send the collier to Luce Bay. The *Tartar* and *Grasshopper* were sent to convoy the torpedo boats to Lamlash. The *Inconstant* returned to the squadron from Lamlash, and was sent in to surrender to the Achill commander, in accordance with umpire's decision.

At 9.30 a. m. Admiral Rowley raised the blockade, and proceeded with the remainder of his squadron, except the *Mercury*, which was missing (chasing FitzRoy), for the rendezvous at Drummore.

At 2.30 p. m. the *Benbow*, *Collingwood*, and *Rover* joined Rowley's flag, having steamed at the rate of 13 knots from Bantry.

At 4 p. m. the *Iron Duke* rejoined.

At 5 p. m. the *Mercury* came up, and reported the escape of the *Rodney* and *Amphion* (she had not seen the *Spider*), and that she had followed them up, but lost them 15 miles northwest of Tory Island. She had reconnoitred the entrance of Lough Swilly upon her return, and made out the *Black Prince*, *Devastation*, *Invincible*, *Hearty*, *Serpent*, and *Curlew* inside. The *Mohawk* (repairing) and the *Tartar*, *Grasshopper*, and Nos. 66, 72, and 80 (coaling) were at Lamlash.

A Squadron.—At 9 a. m. the *Archer* was detached and sent to Holyhead for news; torpedo boats to accompany her and wait orders. The squadron arrived off the Mull of Galloway at 7 p. m., and found the *Mersey* there. She reported the loss of the *Inconstant* and No. 50; also that the *Rodney*, *Amphion*, *Calypso*, and *Spider* had escaped on the night of the 4th. (It will be remembered that the *Calypso* had got out on the night of the 2d, and had been over two days at large.) At 9 p. m. Nos. 81 and 76 rejoined the squadron, and, after communicating with the admiral, parted company again for Holyhead. At 10 p. m. the *Archer* rejoined the squadron, bringing the information that no ships had forced the blockade at Bantry Bay.

Rowley joined the flag of the vice-admiral at midnight in Luce Bay, and the assembled squadron steamed south at once to guard the Channel.

B Squadron.—At 9.40 p. m. the *Warspite* and *Iris* joined FitzRoy in the *Rodney* at the rendezvous off St. Kilda.

MONDAY, *August* 6.

A Squadron.—"Off Holyhead the squadron stopped at 11.15 a. m. *Thames* was sent to Berehaven to recall *Arethusa*; *Thames* then to rendezvous off the Lizard, and *Arethusa* to rendezvous at Portland; *Benbow* sent to Devonport to coal and wait orders; *Conqueror* to Milford Haven for coal, then on to Portland; *Raccoon* to Milford Haven, with orders to send *Rattlesnake* to Portland.

"*Hotspur* rejoined squadron from Milford.

"At 5.30 the squadron was off Milford Haven; at 7 p. m. a torpedo-boat came from Holyhead with dispatches, informing the admiral to a certainty that Tryon had escaped from Bantry Bay.

"At 7.15 p. m. the two admirals held a conference, and shortly afterwards the second division, augumented by *Archer* and No. 79, parted company, and turned northward again, 'to watch Liverpool from Holyhead,' and the first division steamed to the south alone."

B Squadron.—The *Cossack* joined Admiral Tryon at 5 a. m. and was sent ahead to Blackhead Bay for dispatches, thence to rejoin flag at Lough Swilly. The *Hercules*, *Ajax*, and *Hero* en route to Lough Swilly.

The *Severn* joined FitzRoy's flag off St. Kilda at 1.20 a. m., and the squadron, then under his orders, consisting of the *Rodney*, *Warspite*, *Iris*, and *Severn*, started at once on its mission of destruction. Steaming northward outside the Western Islands, Cape Wrath was reached soon after noon, Dunnet Head at 5 p. m., Pentland Skerry at 6 p. m., and Kinnaird Light at 11.30. The eastern coast of Scotland and England lay at his mercy, with no British ship nearer than the Land's End.

TUESDAY, *August* 7.

A Squadron—first division.—"Fog came on in middle watch, and continued all day; speed reduced to 4 knots. *Raccoon* rejoined from Milford, bringing news of two ironclads and one cruiser (Rear-Admiral FitzRoy) having passed Duncansby Head at 6.45 p. m. the day before.

"Fog lifted at 6. 40 p. m. sufficiently to see the Wolf Rock. No. 81 sent to Falmouth to telegraph orders for rear-admiral to rendezvous off the Lizard early on Thursday morning, 9th. *Raccoon* ordered to Devonport to repair steam-pipe.

"*Second division.*—Early in the morning the *Tartar*, *Grasshopper*, and Nos. 66, 72, and 80 rejoined from Lamlash. The *Tartar* was sent to Holyhead for telegrams, and No. 80 to Liverpool Bar for information. At 2 p. m., blowing strong, the torpedo-boats were sent into Holyhead for shelter.

"*B squadron.*—Tryon, with his three ironclads moving leisurely up the west coast of Ireland.

FitzRoy reached Buchan Ness Light at 12.40 a. m. and Aberdeen at 4.15. Fire was opened upon the graving-docks, building slips, and foundries, and a requisition made for £400,000. At 4.50 a. m. course was shaped for the Firth of Forth. At 2.20 p. m. the *Iris* was dispatched to bombard Leith, the three other vessels proceeding up the Firth of Forth to destroy the bridge. Standing out to sea again, Inchkeith was passed at 4.15 and the Bass Rock at 6 p. m. The *Warspite* was then detached to requisition Grimsby and destroy the shipping. The *Severn* was sent to do the same thing at Hartlepool and Scarborough. The *Iris* was sent to a rendezvous latitude 56° 30′ N., longitude 0, to await arrival of remainder of squadron."

WEDNESDAY, *August* 8.

A Squadron—first division.—"Fog all day; unable to accurately fix position of squadron. 5 p. m., *Active* sent to Portland for news. 9 p. m., squadron anchored for the night off Durlstone Head.

"*Second division.*—Off Liverpool. At 9 a. m. the *Mercury* was sent to Liverpool Bar for news; at 10.15 the *Mercury* was sent to Holyhead for small repairs, and the *Tartar* for telegrams. The latter brought back orders from the vice-admiral, in accordance with which the *Neptune*, *Belleisle*, *Archer*, and No. 72 were detached for the defense of Liverpool, and at 2.30 p. m. the remainder of the second division left for the southward. At 3 p. m. the speed was reduced to 4 knots on account of fog. No. 79 was sent to Falmouth and No. 80 to Lundy. At 6.45 p. m. the fog lifted, and speed was increased to 9 knots.

"*B squadron.*—Admiral Tryon reached Lough Swilly at 4.50 a. m.; ordered *Achill* (late *Inconstant*) to cruise on the west coast of Ireland till the close of hostilities, and sailed at 7.20 a. m. for Liverpool, with the *Hercules*, *Ajax*, *Hero*, *Invincible*, *Devastation*, *Curlew*, *Hearty*, and Nos. 45, 57, and 58.

"Admiral FitzRoy, in the *Rodney*, steamed slowly south during the night; at 8.20 a. m. stopped off the mouth of the Tyne, and opened fire with her barbette guns, by compass bearings, on Newcastle, 8¼ miles distant; also engaged a battery at North Shields and destroyed all shipping. Sunderland was next attacked at 10.20 a. m., and a battery which returned the fire was engaged, and more shipping was destroyed. The *Rodney* then proceeded to the appointed rendezvous. The *Iris* had reached this rendezvous 56.30 N., long. 0, at 3 a. m. The *Severn* arrived at 7 p. m. and the *Warspite* at 10."

The damage claimed by FitzRoy to have been done during this raid is thus summarized and commented upon by the Committee of Admirals:

RODNEY, WARSPITE, IRIS, AND SEVERN.

"*Aberdeen.*—£400,000, and all shipping destroyed. Return of shipping not given. Approximate time, thirty minutes.

"*Firth of Forth.*—Edinburgh £1,000,000; Forth Bridge destroyed; 3,000 tons of coal provided for his squadron; live-stock and vegetables requisitioned, and all shipping in Leith Roads destroyed.

"*Iris* remained at Leith seven hours, during which time the shipping, not being numerous, might have been destroyed.

"As, for the purposes of these manœuvres, the Forth was not a 'fortified port,' any resistance which might have been offered to the passage of the squadron past Inchkeith and Kinghorn Ness is not taken into consideration."

RODNEY.

"*The Tyne.*—£500,000 levied on Shields, £1,000,000 on Newcastle, and fire opened on Newcastle at 16,500 yards (8¼ miles) from *Rodney's* 69-ton guns; also all shipping destroyed in the river. No returns furnished. Time occupied, one hour five minutes.

"*Sunderland.*—£1,000,000 levied, and all shipping destroyed. Returns of shipping not given. Time occupied, about half an hour."

SEVERN.

"*Hartlepool.*—£500,000 levied, and shipping (two steamers) destroyed by gun-fire. Time occupied, one hour twenty-five minutes.

"*Scarborough.*—£500,000 levied, two steamers and a camp destroyed. Time occupied, forty minutes.

"During the passage between Hartlepool and Scarborough, in three hours, thirteen steamers under weigh and a fishing fleet were destroyed by the *Severn. The crews were not removed.*"

WARSPITE.

"*Grimsby.*—£500,000 levied; thirty-one steamers and twenty-six sailing vessels destroyed.

"From the time this vessel parted from the flag off Inchkeith, at 4.15 p. m. on August 7, until she reached the appointed rendezvous on the 8th at 10 p. m., she never appears to have gone less than 12 knots in any one hour. She steamed 2 miles up the Humber on the morning of the 8th, firing on the shipping, then altered course 16 points to starboard, and proceeded to sea again.

"Thus in about thirty minutes, and at a speed of 12 knots, this vessel claims to have requisitioned Grimsby and sunk shipping in the Humber, as stated above, and altogether during her thirty hours' absence from the flag, at an average speed of 13 knots, to have destroyed 56,570 tons of shipping, including forty-five steamers and 53 sailing vessels, besides small craft.

"Whilst it is clear that the destruction claimed to have been effected in the course of these raids is, to some extent, fanciful, as regards the time in which such result could be accomplished, it is unnecessary to point out the incalculable mischief which so enterprising an enemy might inflict in even that short time, and how imperative it is to complete the military defenses of our great commercial centres without further delay.

"NOTE.—It is to be observed that, in the execution of this service, the rear-admiral acted in accordance with the orders of his commander-in-chief, '*to destroy, not capture;*' yet, in the case of every vessel destroyed at sea, it would have been necessary to allow the time required to transfer the crew, which, from one cause or another, could hardly be less than one hour for every vessel claimed by each ship; nor is it probable that all steamers in sight would remain to be captured instead of spreading in every direction at their utmost speed."

THURSDAY, *August* 9.

"*A squadron—first division.*—At 4 a. m. fog lifted, and squadron proceeded to Portland Roads, which was reached at 7.30.

"*Mersey, Arethusa, Rattlesnake,* and torpedo-boats 81, 67, 41, and 25 were found there. *Active* came in, after being several hours at the rendezvous, at 8.30 a. m.

"Having taken in all the coal found afloat at Portland, the squadron, all except *Rattlesnake,* sailed at 12.30 p. m. Orders were left for *Benbow, Conqueror,* and torpedo boats to follow on. The *Raccoon* (at Plymouth) was ordered to Portland when ready. The *Northampton, Thames,* and *Mohawk* (the latter having finished repairs at Lamlash) were directed to join the second division. The *Rattlesnake* rejoined from Portland.

"*Second division.*—Arrived off Milford at 5 a. m. The *Agincourt* and *Grasshopper* went in for coal, and at 6.30 p. m. followed the remainder of squadron to the rendezvous off the Lizard."

B squadron.—Admiral Tryon arrived off Liverpool at 6.40 a. m. The *Hearty, Curlew,* and torpedo-boats were sent into harbor. There was a fog, which, lifting at 10 a. m., showed the *Neptune* and a torpedo-boat in the offing making off at full speed. The squadron then passed in over the bar and engaged the forts at noon. The forts had previously been firing on the cruisers and torpedo-boats. The *Belleisle* was seen at anchor off Liverpool, and the light craft, after an exchange of shots, fell back on the main body.

The *Belleisle,* however, soon submitted to the superior force, and hauled her colors down at 1.35 p. m. The Achill admiral renamed her the *Liver,* and anchored his squadron in front of Liverpool, requisitioned the city, and destroyed the shipping.

Admiral FitzRoy joined the *Iris, Severn,* and *Warspite* at the rendezvous at 3.30 a. m. At 5 a. m. his squadron proceeded north, to keep at least 9 miles from land, and to pass northward of the Orkney Islands, and to rendezvous at latitude 57° N., longitude 8° 50′ W. Speed 8 to 9 knots.

FRIDAY, *August* 10.

"*A squadron—first division.*—At 8 a. m. anchored off Broadstairs, under the north foreland. The *Mersey* and *Arethusa* were at once dispatched on lookout duty. At 5 p. m. the *Benbow* and *Conqueror* rejoined. At 7.30 p. m. the whole squadron weighed and stood out, to cruise during the night in the channel. The vice-admiral telegraphed Rear-Admiral Rowley to join him with the second division in the Downs.

"*Second Division.*—Arrived off the Lizard early in the morning. At 9.30 a. m. the *Agincourt* and *Grasshopper* joined. There were then with those two the *Inflexible, Shannon, Iron Duke, Northampton* (temporarily attached), *Tartar,* and *Mercury.* The remainder of his division was supposed by Admiral Rowley to be distributed as follows: *Neptune* with No. 72 off Liverpool; *Belleisle* at Liverpool; *Thames* coaling at Plymouth; *Mohawk* and *Archer* on their way to the Lizard; No. 66 under repair at Holyhead; No. 79 at Falmouth, and No. 80 at Lundy."

"At 2 p. m. *Mohawk* joined from Lamlash. Rear-admiral learned from her of destruction of Liverpool and capture there of *Belleisle.* Having, at 5.15 p. m., received orders from vice-admiral to proceed with second division to join him, rear-admiral telegraphed to his missing ships to proceed with dispatch to the Downs, and at once took his squadron in that direction.

"*B squadron.*—At noon Admiral Tryon left Liverpool, taking with him the captured *Belleisle.* At 7 p. m. he stopped off Holyhead and sent in the *Hearty,* with the torpedo-boats, covered by the *Invincible*, to raid that port. This was done, and No. 66 was captured. Leaving behind the force engaged in the attack upon Holyhead, the squadron sailed for Lough Swilly at 10 p. m.

FitzRoy's vessels en route to rendezvous, passing around the Orkneys."

SATURDAY, *August* 11.

"*A squadron—first division.*—At 5 a. m. returned to former anchorage off Broadstairs. Weighed at 8.30 a. m. and left for the Nore, the cruisers going in to Sheerness. Coaling carried on through the remainder of day and night.

"*Second division.*—Proceeding up channel.

"At 3.15 p. m. *Tartar* was sent ahead to report whether vice-admiral was in the Downs. At 6 p. m. a strange cruiser, supposed to be the *Amphion*, was seen ahead, but soon lost sight of. At 10 p. m. A^2 squadron anchored in the Downs. No information as to the cruiser lately seen was obtainable from the Coast guard.

"*B squadron.*—Admiral Tryon en route from Liverpool to Lough Swilly.

"At 7 a. m. (off Sanda Island) the ships were spread to look out for *Invincible* and her consorts; they proceeded again at 12.20, and reached Lough Swilly 9 p. m.

"Admiral FitzRoy's ships reached the rendezvous, latitude 57° N., longitude 8° 50′ W., at 9.15 a. m., and steered at once for Lough Swilly, going slowly until within 25 miles of the port, when full power was ordered to run the blockade if a British squadron should be found off the port."

TUESDAY, *August* 12.

A Squadron.—At 9 a. m. Rowley received a telegram from No. 66 reporting her capture at Holyhead. At 2 p. m. the vice-admiral with first division was sighted coming towards the Downs from the Nore.

B Squadron.—"1.40 a. m. *Invincible* and *Hearty* arrived at Lough Swilly, followed by the three torpedo-boats at 4 a. m. At 5.30 Rear-Admiral FitzRoy, with *Rodney, Warspite, Iris,* and *Severn,* rejoined the squadron."

The movements of the main bodies of both squadrons having been detailed from day to day, it is necessary to go back to the first breaking of the blockade on the 2d of August and describe the operations of the detached cruisers of B squadron. These are concisely presented and commented upon in the report of the Committee of Admirals:

CALYPSO.

"The *Calypso* was the first to commence the raiding; she broke the blockade of Lough Swilly at 10 p. m. on the 2d August, and proceeded to Port Ellen, where she remained four hours; during this time she captured No. 50 torpedo-boat (belonging to A squadron), and destroyed two steamers, a tug, and the 'coal stores;' thence to Oban, capturing steamers by the way; during her stay there of eight hours, *i. e.*, from 10 p. m. of the 3d to 6 a. m. of the 4th, she claims to have requisitioned the town, besides capturing a one-gun battery and several steamers.

"She was next seen at a British port, when at 6 a. m. on the 18th, she went in to Penzance, and in two hours forty minutes, captured the Coast-guard station (making a prisoner of the inspecting commander) and one steamer; Falmouth was visited on the same evening, and during a stay there of one and a quarter hours—8.30 p. m. to 9.45 p. m.—her captain claims to have seized the Coast-guard station, requisitioned the town, and captured or destroyed Her Majesty's ship *Ganges* and two training brigs.

"Between the dates of the 4th–18th August the *Calypso* was cruising in the track of commerce, and claims for a total of 59,247 tons of shipping captured during that time were sent in.

"It would seem that, with regard to these claims for shipping, the 'Rules as to Captures,' as laid down, were generally complied with by the *Calypso*, and the raids on Port Ellen, Oban, and Penzance—being all undefended—may be considered successful; but it is open to question whether the amount of damage claimed to have been done at Falmouth, which has the protection of Pendennis Castle and St. Mawes Battery, could have been effected at all by one unarmored ship."

SPIDER.

"The *Spider*, which left Lough Swilly with *Rodney* and *Amphion* on the night of the 4th–5th August, broke the blockade at 1 a. m. (5th), proceeding first to Campbelltown; she arrived at that place at 6 a. m., and, after forty minutes stay, during which time over 5,000 tons of shipping was destroyed, she went on to Rothesay, where a stoppage of thirty minutes was considered sufficient for the purpose of sinking five steamers; thence to Greenock, where an hour was spent in 'destroying in detail all the shipping in the Clyde,' of which over 32,000 tons were claimed, besides 'firing on and destroying the principal public buildings near the quay.'

"From Greenock she proceeded up the East Kyle of Bute, then down to Strone Point for the night. After that Cumbrae, Ardrossan, Gigha Island, Genarcardock Point, Crinan, Loch Tarbert, and the sound of Islay were all visited between the 6th and 7th, and at most places large destruction was claimed.

"While it may be considered extremely doubtful whether any cruiser (the *Spider* for the purposes of the manœuvres being so classed) could have done anything like the amount of damage claimed in the time, even if she met with no resistance, yet her movements show that no great obstacle lies in the way of an enemy's cruiser entering any of the ports, including the Clyde, which were visited by the *Spider*, for a hostile purpose, and this fact points to the necessity of the proposed military defenses of the latter place being taken in hand as soon as possible."

AMPHION.

"The *Amphion* left Lough Swilly with *Rodney*, and broke the blockade with her on the night of the 4th-5th August. During her cruise in the Channel and up the east coast of Great Britain she claimed the destruction of much shipping and the capture of the Coast-guard stations at Scarborough and Wick, also, after leaving Lough Swilly the second time, to have visited Bude with a hostile purpose.

"As Scarborough had already been attacked by *Severn* five days earlier, her visit there could not have been of much effect, neither does it seem that any useful purpose was served on the occasion of her visit to Wick, as she was taken there in order that her captain might telegraph to the Achill admiral through the enemy's wires, an impossible condition in war time. In no case, according to her log, does it appear that rules as to capture of shipping were adhered to."

VOLAGE.

"The *Volage* left Berehaven at 9.20 p. m. on the 8th to cruise on the path of steamers between the British Islands and America. Between the 9th and 18th she captured eight steamers and two sailing vessels. In all cases the rules as to capture were complied with, but among her prizes claimed are the *Gallia* and *Servia* with an ocean speed of 15 and 17 knots respectively, while the *Volage* is rated at 13½, and the highest speed she reached during the manœuvres was 11. It is most improbable that she would have captured the Atlantic liners in time of war."

SANDFLY.

"This vessel, whose mission was to cruise off Queenstown, using that port as a base, left Berehaven at 8.30 p. m. August 6, and reached Queenstown at 7 a. m. next day.

She cruised daily off the port on the 8th, 9th, 10th, 11th, 13th, 14th, 15th, and 18th, returning into harbor each evening. During these daylight cruises she claimed to have captured twenty-three steamers, many of them large Atlantic liners, and fifteen sailing ships.

"As in the case of the *Spider* she was for the manœuvres classed as a cruiser. Her reputed full speed is 19 knots, but she had not completed the contractor's trials, and the admiralty decided not to press her beyond 15 during the manœuvres.

"From the entries in her log it does not appear whether in some cases the rules as to capture were adhered to or not, but on the 8th, when the capture of the *Caspian* was claimed, she was absent from her buoy only an hour and ten minutes, and on the 13th between 1.30 and 6 p. m. four sailing vessels and one steamer were claimed, which by the rules is inadmissible; again on the 15th only an hour and a quarter elapsed between the capture of the *City of Rome* and that of a sailing vessel.

"It is to be also observed with regard to the *Sandfly's* capture of Atlantic liners that she was using Queenstown as a base against vessels which were calling off the port, quite unaware of, or indifferent to, its hostile character, an improbable condition in these days of cable communication, especially a fortnight after the outbreak of war."

We now return to the operations of the principal squadrons, which were on the 12th assembled in the Downs and at Lough Swilly.

SUNDAY, *August* 12—(Continued).

A Squadron.—"A second junction of the two divisions being thus formed, the vice-admiral at once dispatched *Northampton* with No. 41 to guard the mouth of the Thames; subsequently *Hotspur* was sent to re-inforce them. Cruisers *Arethusa, Raccoon, Tartar, Mohawk,* and *Rover* were ordered to patrol the Channel, each on an appointed 'beat,' from North Foreland to Land's End. The remaining cruisers on 'scout duty' in and near the Straits of Dover.

"At 6.40 the squadron weighed and stood 'off and on' all night."

B Squadron.—"Admiral Tryon had at Lough Swilly all his squadron, with the exception of the *Rupert* and Nos. 53, 54, 59, and 64 at Berehaven; the *Amphion, Volage, Calypso,* and *Sandfly* cruising; and Nos. 60 and 78 at Queenstown. The *Liver* (late *Belleisle*) and No. 90 (late No. 50) were with his flag, and the *Achill* (late *Inconstant*) was cruising off the west coast of Ireland. The squadron was coaling, and suffering great delay because the coal was all in one large collier."

MONDAY, *August* 13.

A Squadron.—"An enemy's cruiser was reported as having been chased by *Thames* and *Raccoon* off Sandgate the evening before. *Arethusa* dispatched to Portsmouth for fresh provisions. *Neptune* rejoined squadron from Plymouth.

"Anchored in Downs at 4 p. m."

B squadron.—Still coaling, but the operation additionally delayed by bad weather.

TUESDAY, *August* 14.

A squadron.—"Commodore Markham, with three cruisers, *Active, Thames,* and *Mersey,* sent to relieve *Hotspur* and *Northampton* in watching the estuary of the Thames. 3.15, *Grasshopper* rejoined from Plymouth and Portsmouth. 5.45 p. m., squadron weighed from the Downs and cruised in channel. 7.48 p. m., *Arethusa* returned from Portsmouth."

B squadron.—At Lough Swilly. The *Cossack* was sent to cruise off the mouth of the harbor during the night.

WEDNESDAY, *August* 15.

A squadron.—"5.20 a. m., *Northampton* and No. 41 rejoined from the Nore. 10.30, *Hotspur* also rejoined. 2.48 p. m., returned to anchorage in Downs. Received news of *Amphion* passing west of Dunnet Head at 12.50 p. m.

"Picket boats sent out during the night."

B squadron.—At Lough Swilly. The *Serpent* was sent out to scout during the night.

THURSDAY, *August* 16.

A squadron.—"*Mercury* sent to reconnoiter a strange squadron of four ironclads and two cruisers; the strangers were found to be French. No. 80 rejoined from Pembroke.

"Torpedo-boats on 'picket duty' during the night."

B squadron.—"At 11 a. m. (16th) *Warspite* sailed for Berehaven. At 1.30 *Cossack* was sent out to communicate orders to *Achill* (late *Inconstant*), and at 4 p. m. *Amphion* arrived from the northward.

"At 5 the ironclad squadron with *Severn* and *Iris* weighed and left Lough Swilly; they were joined by *Cossack* outside.

"At 6.45 *Rodney* (flag of Rear-Admiral FitzRoy), *Severn*, and *Iris* parted company, to be joined afterwards by *Warspite* at a rendezvous, on a special mission of destruction. At 7 p. m. *Liver* (late *Belleisle*) was ordered back to Lough Swilly."

FRIDAY, *August* 17.

A squadron.—"At 2 p. m. fleet weighed and stood to the northward. Commodore, with cruisers, recalled from the mouth of the Thames; No. 79 sent to watch at the Nore; Nos. 72 and 76 rejoined from Pembroke.

"Detached squadron of six cruisers, under Commodore Markham, sent to watch the channel from Cape Grisnez to Dover.

"Ironclad divisions with the flag cruising in the North Sea and as far as South Foreland in the Channel.

"Remaining cruisers on scout duty.

"This distribution remained unaltered until noon on the 20th, when hostilities ceased and the fleet dispersed."

B squadron.—"Steaming down the west coast of Ireland. At 6 p. m. *Cossack* was dispatched to reconnoiter Berehaven."

SATURDAY, *August* 18.

B squadron.—"The rear-admiral commanding B squadron, with his six ironclads, arrived at Berehaven at 5 a. m. The boom and other defenses were broken up; men from the batteries and signal stations were embarked, and at 6 p. m. he left again with the same ships and *Cossack* for the 'Chops of the Channel.'

"Meanwhile Admiral FitzRoy, at his rendezvous, southwest of Cape Clear, had been joined by *Warspite* at 3 a. m. He then proceeded for the channel at good speed. At 8 p. m.—in mid channel—*Iris* and *Severn* were dispatched at full speed to 'look up' Exmouth, Bridport, and Westbay (Portland)."

SUNDAY, *August* 19.

B squadron.—"*Amphion*, which had left Lough Swilly at 8.30 the morning before, arrived off Bude at 2.30, and stopped off the place one hour, then steamed towards the Land's End.

"*Iris* and *Severn* did the work of destruction allotted to them during this day, and joined Admiral FitzRoy with *Rodney* and *Warspite* at 4 p. m. off the Casquets. These four ships then steamed up channel in company.

"Sir George Tryon with his ironclads and *Cossack* arrived in the channel during the night."

MONDAY, *August* 20.

"At noon hostilities ceased, the position of B squadron being at that time roughly as follows:

"*Rodney*, flag of rear-admiral second in command, *Warspite*, *Iris*, and *Severn* between Dungeness and Owers.

"*Hercules*, flag of rear-admiral commanding, *Ajax, Hero, Invincible, Devastation, Black Prince,* and *Cossack* off Bolt Head.

"*Calypso* 20 miles southwest of Plymouth.

"*Amphion* off the Wolf Rock.

"*Volage* and *Sandfly* cruising off southwest coast of Ireland.

"*Liver* (late *Belleisle*), *Serpent, Spider, Curlew, Hearty*, and seven torpedo-boats, Nos. 45, 51, 52, 55, 57, 58, and 90 (late 50), in Lough Swilly, with *Achill* (late *Inconstant*) guarding the entrance.

"*Rupert*, three coast-guard tenders, and four torpedo-boats, Nos. 53, 54, 59, and 64, at Berehaven.

"Two torpedo-boats—Nos. 60 and 78—at Queenstown.

"All vessels left for their respective stations and ports as directed by admiralty order."

LOSSES OF BOTH SQUADRONS UNDER THE RULES.

Conflicting claims have frequently been referred to. They are too numerous to recapitulate in detail. In many cases the umpires failed to render a decision, and in some others they disagreed.

The number of umpires was in fact entirely inadequate for the work which they were expected to do. After an examination of the claims and counter-claims, the committee of admirals reported the following as in their opinion the losses sustained by each side:

A's losses.—Torpedo-boat No. 50, August 3; *Archer*, August 3; *Inconstant*, August 3; *Tartar*, August 4; *Arethusa*, August 5; *Belleisle*, August 9; Torpedo-boat No. 66, August 10; two torpedo-boats by fire of their own ships, July 24; *Vulture* (collier), July 27. Total, one iron-clad, four cruisers, four torpedo-boats, and one collier.

B's losses.—Torpedo-boats—No. 51, August 3; No. 90 (late No. 50), August 3; No. 78, July 31; *Curlew*, August 5. Total, one cruiser and three torpedo-boats.

COMMENTS ON THE MANŒUVRES.

The work of blockading was very severe upon all line officers. As it was not known by A squadron that B squadron would not run the blockade until August 3, their vigilance was not permitted to relax during the ten days, and the constant lookout for torpedo attack was very trying. In actual warfare where casualties would occur, it would be necessary to have additional officers attached to a ship; and if all ships in reserve were commissioned, and all peace complements increased, this would involve the maintenance in a state of readiness for service of a large number of officers either on the active list or in reserve. Admiral Jurien de la Gravière says that a full supply of instructed officers is the most precious of possessions at the outbreak of a war; and he attributes the poor work of the French navy after the French revolution to the fact that many trained officers of the old *régime* had emigrated or been guillotined.

TORPEDO-BOATS.

The blockade showed torpedo-boats of the types now existing to be of great value to the blockaded, but to be illy adapted for blockading work. Boats actually capable of keeping the sea in all weathers, with reasonable safety and comfort, would be invaluable aids to a blockading squadron, but no such have yet been produced, nor is it probable that they will be produced until the present limits of size are far extended.

The present first-class boats rapidly wear out their crews. In bad weather no cooking can be done, and the men can not sleep; they are constantly drenched with sea water, and the question becomes simply one of physical endurance. Their machinery is constantly needing repair, and they demand too frequent attention in the matter of water and coal. Always in danger from the elements, they are a constant source of anxiety and embarrassment to an admiral; and during a blockade of any length the deterioration of their machinery and the exhaustion of their crews would soon take away largely from that speed and vigilance which constitute their principal value.

The Committee of Admirals considered that first-class torpedo-boats might with advantage accompany a blockading squadron if they were carried in a suitable vessel—an improved *Hecla;* also that second class boats, as carried in the ironclads, were useful. But it considered the new type of wooden vedette boat to be a better equipment for sea-going battle ships than the steel second-class boats.

It must, however, be borne in mind in this connection that the weather to be expected makes a great difference. Bad weather is of common occurrence in British waters, and July, 1888, was unusually stormy. A different report might be obtained from torpedo-boats with a blockading squadron in the Mediterranean or in the Gulf of Mexico.

Torpedo-boats with the *blockaded* squadron occupy a quite different position. They lie quietly in port when unemployed, their crews are rested and refreshed, and their steam machinery kept in a high state of readiness and efficiency. When reconnoitring the blockaders, or making a dash upon them at night, their best qualities are called into exercise, unhampered by previous fatigue or exposure.

To keep blockading vessels on the alert, and thus increase their consumption of coal and exhaust their crews, first-class torpedo-boats with a blockaded squadron are of great value.

COAL AND COALING.

The frequent mention of colliers and coaling throughout the narrative of the manœuvres is a constant reminder of the importance which this supply now bears to all naval operations. No advance was made in coaling at sea, which is still a problem unsolved. The blockading ships were obliged to withdraw, one or two at a time, to sheltered anchorages, thus weakening the blockading force, and affording the enemy an opportunity for making an attack or an attempt to escape. They were also, being in an enemy's waters, exposed to attack from batteries or torpedo-boats while so engaged in coaling. Several times it was necessary to recall battle ships in great haste when signs of activity in the blockaded ports were observed.

Several small colliers are preferable to one large one. The coaling of a fleet is much delayed if the vessels must take their turns alongside of one large collier.

This was the case at Lough Swilly, when the divisions rejoined on August 12. All of Admiral Tryon's coal (2,300 tons) was in one collier, and the coaling was very slow. This defect was observed and commented upon in the Italian manœuvres of 1887, when 4,000 tons of coal were sent to Sicily in one ship.

The facilities for taking coal on board ship are poor, and the performances were various. It took the *Arethusa* over six hours at Milford Haven, on July 25, to take in 100 tons from a lighter. The *Mersey* was able to take in only 62 tons in eleven hours (at night). The *Archer* took in 170 tons from the *Nessmore* in Dunmanus Bay on August 3 in a little over five hours. The *Agincourt* after the manœuvres took in between 500 and 600 tons from a collier alongside in twelve hours.

The two last performances were very creditable. The necessity of supplying smokeless coal in time of war became evident at the beginning of the manœuvres. Volumes of black smoke poured out of the funnels when the fires were pressed, the new ships making more than those of old type.

SIGNALS AND COMMUNICATIONS.

The system of private signals employed proved defective. Torpedo-boats were repeatedly fired upon by their friends. The introduction of these little craft into warfare, their rapid movements between the opposing lines, and the fact that these movements are made at night, increase the importance of this feature of naval operations. It is certain that with the present state of knowledge of the subject mistakes would be made, with disastrous results.

Signaling incompetency was much complained of. The signal staff in many ships was said to be "lamentably weak, imperfectly trained, and discontented with its lot."

The work done by the Coast-guard signal stations in transmitting intelligence was most valuable. Sub-Lieutenant Schrubb, in charge of the intelligence department in the *Hercules*, reported that he had received twenty letters and six hundred and two telegrams while at Berehaven and that only 3 per cent. of the information so obtained was unimportant. The value of similar information in real war would be incalculable; and Lieutenant Schrubb points out that it would be increased if the Coast-guard stations were connected with each other by electric telegraph. Thus the necessity for making the signal stations around the coast accessories of the naval defense was fully presented by the manœuvres. Both Admiral Baird and Admiral Tryon were entirely dependent for a time, after the blockade was raised, upon the information which they furnished.

The great importance of improved means of communication along the lines of trade, to inform merchant vessels of the existence of war, was also demonstrated.

PROTECTION OF THE CREWS.

Discussions of the probable effect of modern projectiles brought to the front several criticisms of the system of partial armor.

Broad Arrow said that it was curious that the development of *unprotection* should have gone so far in England with the knowledge existing of the fearfully destructive effects of shell fire. British officers exclaimed, after the slaughter at Sinope of Turkish sailors by Russian shells, "For God's sake keep out the shells." A correspondent gave expression as follows to the opinion of the *Rodney's* officers respecting that ship: "With nothing protected but her engines, magazines, and barbette guns, her decks would be a regular shambles in action." The attention, called to the subject by the manœuvres, developed a growing conviction that light side armor is essential to fighting a ship to the best advantage; otherwise she may be placed out of action through loss of men.

This conviction was strengthened by the *Resistance* experiments which took place at Spithead while the squadrons were assembling.

STEAMING EFFICIENCY AND ENDURANCE.

From all sides during the manœuvres came complaints of defective machinery. The squadrons were constantly impeded in their speed and in their movements by "lame ducks" needing repairs.

At the very beginning of the manœuvres the best speed that the *Rupert* could make was 8 knots. While Rowley was steaming as fast as his squadron could travel to, join Baird before Tryon's divisions should effect a junction, the *Shannon* kept up 9 knots with difficulty, and another ironclad dropped astern, making less than 9. The *Inflexible* also fell behind, from her starboard engine, breaking down, and the steam pipes of the *Thames* gave trouble. The *Agincourt*, an old ship, was steaming easily at the time under two boilers. The old ships in fact seem to have done very well. The vessels that appeared to travel with the greatest ease and least smoke in Tryon's squadron were the *Black Prince*, built in 1861; the *Hercules*, in 1868, and the *Devastation*, in 1871. It is thought that new machinery in the *Black Prince* and in the *Agincourt* class would make them efficient armored cruisers. They have capacity and length for speed, enough armor to stop machine-gun and high explosive shells, and heavy shells would pass through them from side to side without bursting.

On the passage of Baird's squadron from Bantry Bay to the Mull of Galloway, the *Hotspur*, *Northampton*, and *Active* had difficulty in keeping up 10 knots.

Almost every one of the fast cruisers failed to steam up to her nominal speed, or to maintain a maximum steam pressure when it was reached. The *Mersey* had steamed at the speed of only 14½ knots from Bantry Bay to Lough Swilly, when sent to warn Rowley of the escape of Tryon's ships, yet was obliged to slow down for several hours to clean tubes and get things to rights. The *Severn* was much distressed by the speed that she made for a short time while running the blockade. The *Mercury* was the only cruiser in A squadron capable of making 16 knots continuously for forty-eight hours. The *Mohawk* class failed in boilers and boiler-tubes. The *Raccoon* practically broke down. The *Archer* and *Cossack* had their boilers re-tubed before they had been three months in commission. The *Serpent* was almost constantly under repairs at Lough Swilly.

The *Rattlesnake* class proved entirely too delicate for rough work. "In point of fact," said a correspondent of the Broad Arrow, "we are in this position: The least manœuvres may be rendered abortive by the inefficiency of our steam power. Whatever else the present campaign brings out, it will demonstrate this to a certainty. There is not an officer of either of the four operating squadrons that feels the least confidence in his ship to steam in an emergency."

The frequent failures to maintain steam pressure and speed were probably due largely to the inexperience of stokers.

In view of the failure of ordinary boilers at high steam pressures, inquiries and experiments as to the practical employment of tubulous or coil high-pressure boilers will be followed with increased interest.

INSUFFICIENCY OF CRUISERS.

Admiral Sir G. P. Hornby gives the above as the first lesson taught by the manœuvres, and says that if Admiral Baird had had more scouts he would have learned what force had escaped from Bantry Bay, and would have taken measures accordingly.

The cruisers, when efficient, were masters of the situation, and the manœuvres showed that a greater number of them would add largely to the naval strength of England. Some of them should have the highest speed, an efficient battery, and some side armor; and these features can be combined only in a vessel of large size. Others, lightly armed and unprotected, but strongly built, with good steaming and sea-going qualities, would find their principal occupation in scouting, to collect information and keep touch of the enemy. The most valuable quality in either class is reliability as to speed and steaming endurance. Too much has been sacrificed to lightness of hull and machinery.

The strains of weak hulls throw the machinery out of line, and light parts of the latter, calculated for working under the best conditions, are injured or broken by the unequal strains thus produced.

The entire construction should be more solid, and this will necessitate for the same speed larger ships.

THE FORCE NECESSARY TO MAINTAIN A BLOCKADE AND THE ADVANTAGES OF A BASE NEAR BY.

The Committee of Admirals reported as follows:

> Under the altered conditions which steam and the development of attack by locomotive torpedoes have introduced into naval warfare, it will not be found practicable to maintain an effective blockade of an enemy's squadrons in strongly fortified ports by keeping the main body of the fleet off the port to be blockaded, unless the blockading battle-ships are in the proportion of at least five to three of the blockaded, to allow a sufficient margin for casualties to which the enemy's vessels in a secure harbor would not be exposed, and the necessary periodical absence of a portion of the blockading squadron for the purpose of replenishing fuel, making good defects, etc. A still larger proportion might be necessary if the area to be covered by the blockaders was extensive.
>
> Provided that a suitable anchorage could be secured in the immediate neighborhood of the enemy's stronghold, the advantages would be in favor of the iron-clad fleet occupying such a position and maintaining a sufficient number of swift look-out vessels off the port in direct communication, by signal or cable from a telegraph look-out ship, with the admiral. In such case the proportion of blockading battle-ships should not be less than four to three, and the squadron should be amply provided with colliers and kept coaled up to full stowage, as it would be necessary to have steam always ready to close with the enemy should he leave his port, and endeavor to bring him to immediate action.
>
> We do not consider that a distant base would answer in this case.
>
> It should be the special object in the construction of Her Majesty's ships to insure their having superiority of speed over the vessels of similar class of all other maritime powers.
>
> To insure having force sufficient to follow enemy's cruisers running a blockade without detriment to their general duties off the port, the proportion of fast cruisers employed in blockading should not be less than two to one of the blockaded, observing that there should always be at least one cruiser for every battle-ship in the blockading fleet for the maintenance of an efficient inshore squadron.

Admiral Hornby, reasoning independently, had fixed the proportion of ironclads necessary to blockade a squadron as eight to five, or four and four-fifths to three, always in front of the port ready to fight or chase; and to this force he added a percentage to allow for ships absent coaling or refitting. This percentage would depend upon the distance of the base from the port blockaded. For a blockade of Toulon, for example, with Malta as a base, he allows fifty per cent. That is, to blockade fifteen battle-ships at Toulon would require twenty-four off the port, and twelve absent for coal and repairs—thirty-six battle-ships in all.

Admiral Hornby also assigns two cruisers to every ironclad in addition to those which are cruising independently or in flying squadrons to protect trade.

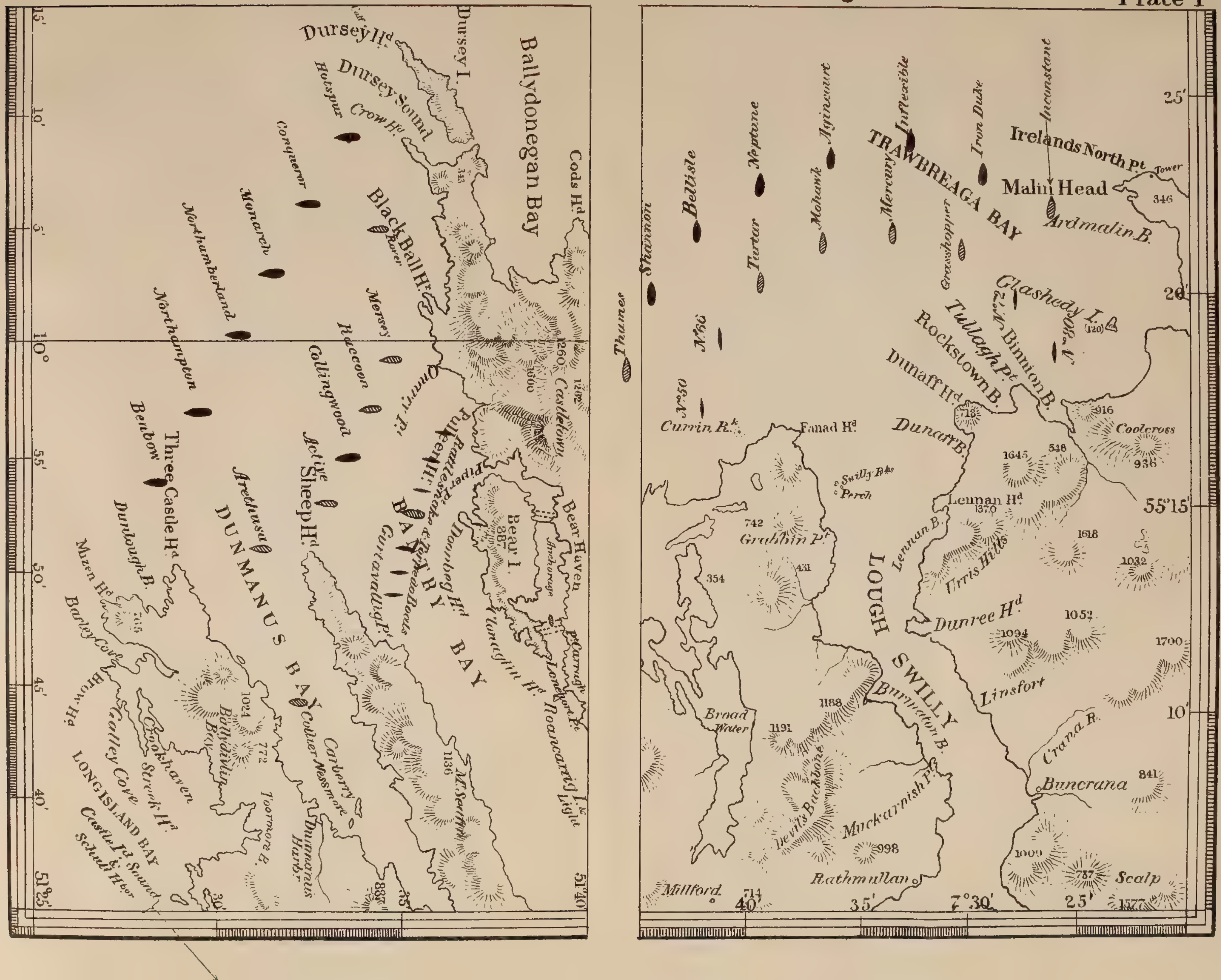
THE STRATEGY OF THE MANŒUVRES.

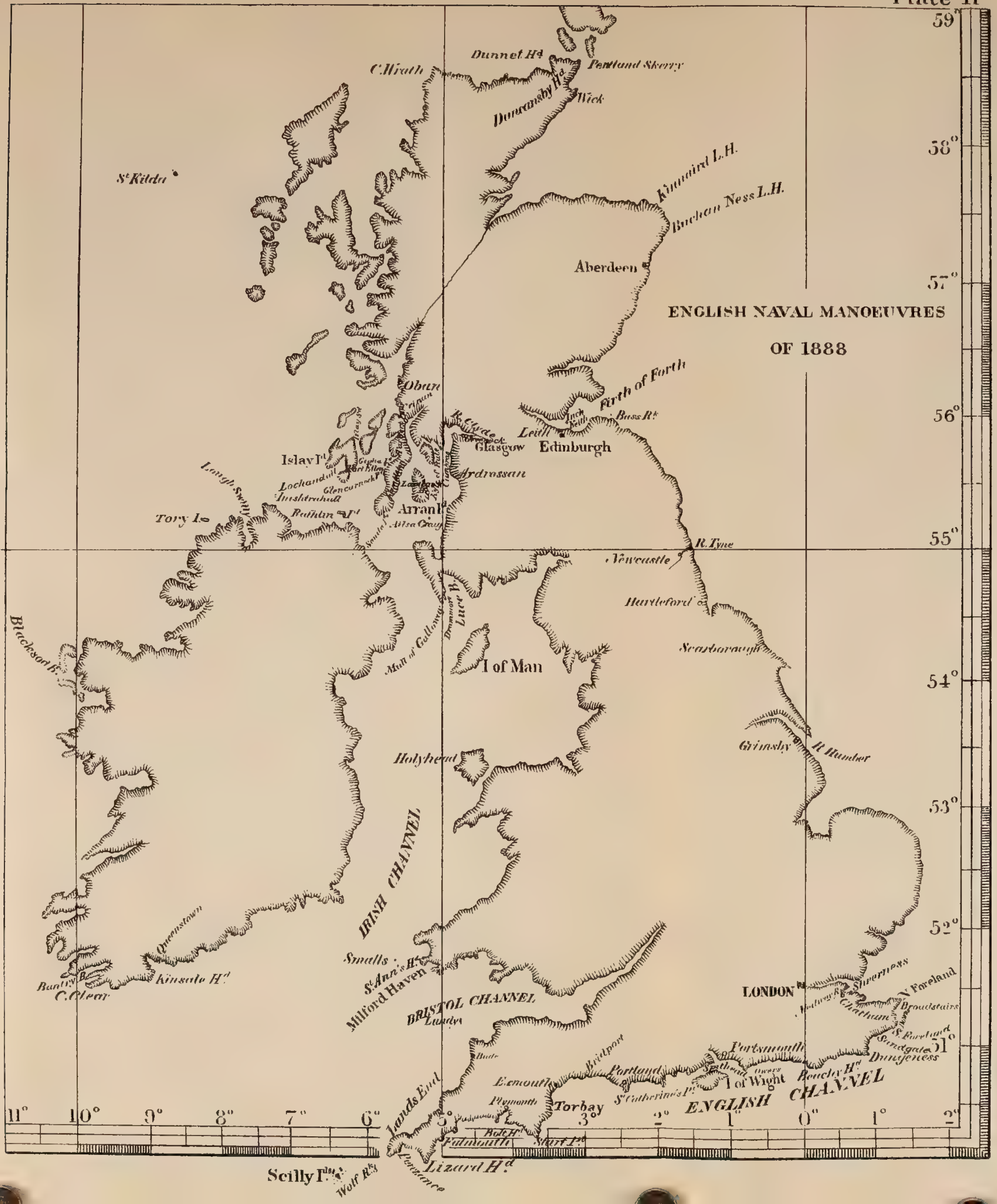
No measures appear to have been taken to protect commerce or undefended ports after the blockade was raised. The enemy was not pursued. "A" squadron acted entirely upon the defensive, first to protect its second division, secondly to protect London, and sacrificed everything

ENGLISH NAVAL MANOEUVRES OF 1888

The Blockade of Bantry Bay and Lough Swilly

Plate I





ENGLISH NAVAL MANOEUVRES OF 1888

else respectively to these objects. The rendezvous at the Mull of Galloway, on August 5, effected to secure Rowley's safety, left both roads to London open to the Irish squadrons. FitzRoy did go around the North of Scotland. Tryon might, with equal ease, have entered the Channel (whether he had or had not escaped from Bantry Bay on the night of August 3) and might have bombarded London while Baird's ships were drifting about the Land's End in a dense fog. Rowley was sent back on the 6th to watch Liverpool, but was recalled just in time to allow Tryon to carry out his plans and capture the *Belleisle.*

If the protection of London was of paramount importance at any period of the manœuvres, it was equally so from the moment of raising the blockade, and it is difficult to understand why Admiral Baird did not guard the channel at once, and let Rowley look out for himself. Some chances must be taken in war, and in manœuvres, and a chance was in fact taken later when Rowley was sent back to guard Liverpool, the vice-admiral commanding being at that time in ignorance of the whereabouts of Tryon's divisions.

Admiral Hornby says that, in the event of war, England must have, besides her blockading squadrons, others to protect the channel, and a strong home fleet between Torbay and the Downs. The manœuvres of 1888 might have been of more value to the student of naval warfare if this home fleet had been supposed to exist, leaving Admirals Baird and Rowley free to pursue the Achill's squadron and to protect commerce and the coast. The Achill admirals were entirely unhampered in their movements, and the game, after August 4, was played by one side.

FRANCE.

THE JUNE MANŒUVRES.

The squadron of evolution, Vice-Admiral Amet commanding, Rear-Admiral Devarennes second in command, executed manœuvres of attack and defense upon the coast of Algeria, the first division defending, the second attacking. The latter had the easier task and succeeded in evading the vigilance of the defenders, bombarded Oran, and captured the *Faucon* and two torpedo-boats.

The squadron then rendezvoused at Algiers, and the *Faucon*, whose machinery needed repairs, was replaced by the *Inconstant*, commissioned at Toulon in twenty-four hours for this purpose.

On June 19 Admiral Devarennes sailed for Ajaccio in Corsica with the ironclad *Dévastation*, the dispatch vessel *Inconstant*, and the high-sea torpedo-boats *Balny* and *Déroulède*, and was joined later by the ironclad *Redoutable.* The remainder of the squadron, consisting of the ironclads *Colbert*, *Amiral Duperré*, *Courbet*, *Indomptable*, cruiser

Milan, torpedo cruisers *Faucon* and *Condor*, torpedo dispatch vessel *Couleuvrine*, No. 151, and two other high-sea torpedo boats, was to blockade Admiral Devarennes in Ajaccio, the ships maintaining their supply of coal while at sea off the port. The transport *Caravane* was dispatched from Toulon with 500 tons of coal to furnish the material for this feature of the exercises.

The blockaded ships made several unsuccessful attempts to break the blockade, usually accompanied with sharp engagements. Finally, on the night of the 25th, the *Redoutable* escaped, which put an end to the manœuvres. Admiral Devarennes appears to have employed the tactics so successfully used later at Bantry Bay. His division separated and one part made a feint, while the other escaped. But the escaping ironclad did not get away unobserved. It is said that she was exposed to the fire of two battle ships for thirty-six minutes, and the validity of her claim to have escaped was disputed.

The rules which controlled decisions as to disputed points have not been published, nor does it appear what success attended the operation of coaling at sea, nor how far the experiment was carried.

Complaint was made of the light structure of the torpedo boats, their liability to injury, their poor sea-going qualities, and the serious strain upon the endurance of their crews; and it was again asserted that these crews would have to be frequently relieved to keep the boats in a state of efficiency.

On the night of the 26th of June a torpedo boat attack was made upon Toulon. The forts and batteries, eighteen in number, were manned by twelve hundred marine infantry. The semaphores were guarded by detachments and light artillery. The flotilla attempted to enter the port, but was met by a destructive fire, and the attack was adjudged to have been repelled.

SCHEME OF THE OPERATIONS IN AUGUST AND SEPTEMBER.

These manœuvres had two distinct objects:

(1) To test the state of preparation at Toulon by mobilizing a certain number of battle-ships and cruisers in the Second Category of the Reserve.

(2) To execute various tactical manœuvres, and test the mobile defense of the Fifth Maritime Arrondissement—the Mediterranean coast of France.

These two operations were entirely separate and distinct.

The mobilization at Toulon was purely a test of the state of readiness of material. There was no mobilization of personnel in the usual acceptation of that term—no calling of Reserves into service—but simply the employment to the best advantage of the men actually in service and immediately available.

The ships commissioned were manned with reduced crews formed of men in the naval barracks, and those under instruction in the several school ships.

Briefly the points to be determined by the mobilization were as follows:

(1) The time necessary, with the existing organization, to send to sea the battle-ships in the Second Category of the Reserve.

(2) Their fitness for action when so commissioned and despatched.

(3) The sufficiency of the resources of the Fifth Maritime Arrondissement to complete the squadron of evolution, and to commission a second squadron without calling any class of the Reserves into active service.

OPERATIONS OF THE SQUADRON OF EVOLUTIONS AUGUST 20–25.

Simultaneously with the mobilization at Toulon, and before the mobilized ships had joined the squadron of evolutions, this squadron conducted experiments against the coast east of Toulon, defended by the despatch boat *Corse*, and eight torpedo boats of the mobile defense.

The squadron of evolutions, commanded by Vice-Admiral Amet, and consisting of the ironclads *Colbert* (flag), *Dévastation* (flag of Rear-Admiral Devarennes, second in command), *Amiral Duperré*, *Courbet*, *Rédoutable*, *Indomptable*, the cruiser *Milan*, torpedo cruiser *Condor*, and torpedo despatch vessel *Couleuvrine*, left Algiers at 8 a. m., August 20, and appeared off the coast of Provence on the 22d. The *Corse* and her flotilla of torpedo boats also left Toulon on the 20th and steered to the eastward.

During the nights of the 21st, 22d, and 23d of August exercises took place between the semaphore stations and the torpedo boats.

The number of signal and lookout men at the former was doubled The torpedo boats explored the coasts and endeavored to escape the vigilance of the signal stations, which, on their part, were on the alert to discover and communicate the movements of the boats.

The squadron of evolutions manœuvred upon the coast from the 22d until the 25th, and the torpedo boats kept it in view.

The semaphores signaled the presence of the squadron considered as a hostile force.

Several unsuccessful night attacks were made by the torpedo boats upon the squadron.

On the 24th the naval battalions of the squadron were disembarked in the Gulf of St. Tropez to simulate the destruction of the semaphores.

Lieutenant Weyl says in Le Yacht of August 29:

> Admiral Amet baffled the vigilance of the torpedo boats, repelled their attacks with a destructive fire, and worked all the hypothetical damage included in his programme. In a word, he was absolute master of the sphere of hostilities. In this little war of four days there again occurred the fantastic performances of the torpedo boats, signaling a torpedo discharge at 50 meters distance from an iron-clad after having been exposed to a fire which would certainly have sunk them.

Apropos of these futile attempts, Lieutenant Weyl quotes a French officer of merit as follows:

> If I were charged with directing a torpedo boat attack against a fleet I would sacrifice an iron-clad to support the flotilla; and I believe that in this way I could inflict upon the enemy a still greater loss. But unsupported torpedo boats can never accomplish anything; they may make a lucky hit, but it is like a chance in a lottery.

This is rather a different opinion from that produced by the naval manœuvres in Great Britain, which held that torpedo boats for the defense—*i. e.*, with a blockaded squadron—were of the greatest practical value. But in this case the French squadron was not blockading, but operated, at least a great part of the time, some distance off the coast. The torpedo-boats had to search the squadron and go out to attack it. They were then obliged to attack several ships, acting in concert, instead of one isolated from the others in her blockading station. And the weather at that season in the Mediterranean is almost invariably clear and smooth, facilitating greatly the use of the electric light and the discovery of the approach of torpedo-boats, and the accuracy of a repelling fire.

These manœuvres were entirely unconnected with the mobilization at Toulon. They terminated at 6 p. m. August 25, the squadron of evolutions anchored in Hyères Roads, and the *Corse* with her flotilla returned to Toulon.

THE MOBILIZATION.

On the 23d of August, at 1 p. m., Vice-Admiral du Petit Thouars, préfet maritime at Toulon, received the order to mobilize the ships previously decided upon, and at 2 p. m. the movement began. The ships mobilized under this order were five battle-ships, three armored cruisers, and four unarmored ships, as follows:

Battle-ships: *Friedland*, *Richelieu*, *Trident*, *Caïman*, *Terrible.* Armored cruisers: *Duquesclin*, *Bayard*, *Triomphante.* Despatch vessels: *Papin*, *Inconstant.* Torpedo cruiser: *Faucon.* Torpedo despatch vessel: *Flèche.*

The ships had all their material embarked except powder, torpedoes, small arms, and provisions. The officers reported in half an hour after the order was given, and within an hour twelve hundred men had marched on board in complete readiness for service.

The ships were towed to the mooring buoys in the roads, and all tugs, boats, launches, and lighters were called into requisition to carry powder and stores. Provisions for fifteen days were taken on board.

The school-ships *Japon*, *Couronne*, and *St. Louis* came in from Hyères in order to aid, with their contingents under instruction, in making up the needed crews.

On the 24th the minister of marine gave the order to mobilize the following torpedo boats, twenty in number, remaining at Toulon:

High-sea boats of 67 tons: *Capitaine Cuny*, *Deroulède*, *Doudart de*

Lagrée, *Challier*, and No. 151, formerly the *Gabriel Charmes*, equipped as a torpedo boat destroyer.

First-class boats: Nos. 26 and 27 of 45 tons, and No. 99 of 54 tons. Second-class boats of 27 tons: Nos. 25, 33, 31, 35, 39, and 43. Vedette boats of 11 or 12 tons: Nos. 29, 30, 56, 57, 58, 59.

The mobilization was conducted rapidly and with perfect order. Each ship, when prepared to go to sea, was dispatched at once to Hyères to report to Admiral Amet.

There was no squadron organization whatever at Toulon. The *Terrible* and *Faucon*, the last ships to get off, left Toulon at 6 p. m., August 25, fifty-two hours after the order to mobilize. The torpedo-boats all got away from Toulon the same evening.

The forts and batteries in the vicinity of Toulon were manned, and placed in condition to defend the port.

As in England, so in France the order to mobilize did not take the dock-yard authorities by surprise. Admiral du Petit Thouars had been in previous consultation with the minister of marine; it was known what ships would be included in the order, and as early as August 20 there was great activity in the Toulon Arsenal to put them in readiness. The officers and men were all prepared and awaiting the signal.

This inevitable notice in advance takes away to some extent from the value of a mobilization test. Nevertheless, admitting the special preparation and the limited scope of the operation, it must be said to the credit of the French system of organization, that the ships were equipped with method and dispatch, and, apart from the question of reduced crews, were sent to Hyères in very good condition. The slow embarkation of powder was, as in England, one of the principal causes of delay. The facilities for receiving and stowing powder on board ship have not increased with the weight and size of cartridges.

The time allowed for getting ships of the Second Category of the Reserve into fighting shape is ten days; therefore the ships mobilized at Toulon had eight days after sailing in which to complete their organization, make trials, drill the new men, and settle down.

EXERCISES AND MANŒUVRES.

All the ships and the first-class and high-sea torpedo boats joined the flag of Admiral Amet in Hyères Roads. The second-class boats and vedettes were divided into two groups, of which one cruised to the west of Toulon, and the other remained in reserve within the breakwater at Toulon Roads.

The *Corse* and her flotilla remained at Toulon.

From the 26th until the 30th of August the ships at Hyères were exercised at battery, small-arm, and torpedo drills, fitting defense nets, managing the electric light, and day and night signaling.

A programme of exercises for the torpedo boats was laid down for each of the ten days of the manœuvres. It included scouting, firing torpedoes at a moving target, night attacks upon the squadron, target firing from revolving cannon, and inspection by the vice-admiral commanding.

On the 30th of August tactical manœuvres began. The fleet was organized into two squadrons and each squadron into two divisions, as follows:

FIRST SQUADRON.

Vice-Admiral Amet, commander-in-chief.

First division: *Colbert* (flag), *Courbet, Friedland.*
Second division: *Amiral Duperré, Caïman, Terrible, Duquesclin.*
Cruisers of the first squadron: *Couleuvrine, Milan, Inconstant.*

SECOND SQUADRON.

Rear-Admiral Devarennes, commanding.

Third division: *Dévastation* (flag), *Trident, Redoutable.*
Fourth division: *Indomptable, Richelieu, Bayard, Triomphante.*
Cruisers of the second squadron: *Papin, Condor, Flèche, Faucon.*

On the 30th, at 8.30 p. m., a torpedo-boat attack was made upon the fleet. Eight boats from the mobile defense of Toulon were joined to the six cruising with the fleet to make this attack.

The armored vessels were covered on the land side by the cruisers, too few in number to act as scouts in all directions. The search-lights were ordered to be so directed as to keep the entire horizon continually illuminated. The defense nets were not rigged out, sole dependence being placed upon the electric lights and the secondary batteries. The flotilla was divided into four groups, which attacked simultaneously from four different directions. Several torpedo boats claimed to have made successful discharges, but the tenor of the French correspondence indicated that the advantage lay with the fleet. Two boats, Nos. 38 and 68, blinded by the beams of light, collided, and each suffered considerable injury.

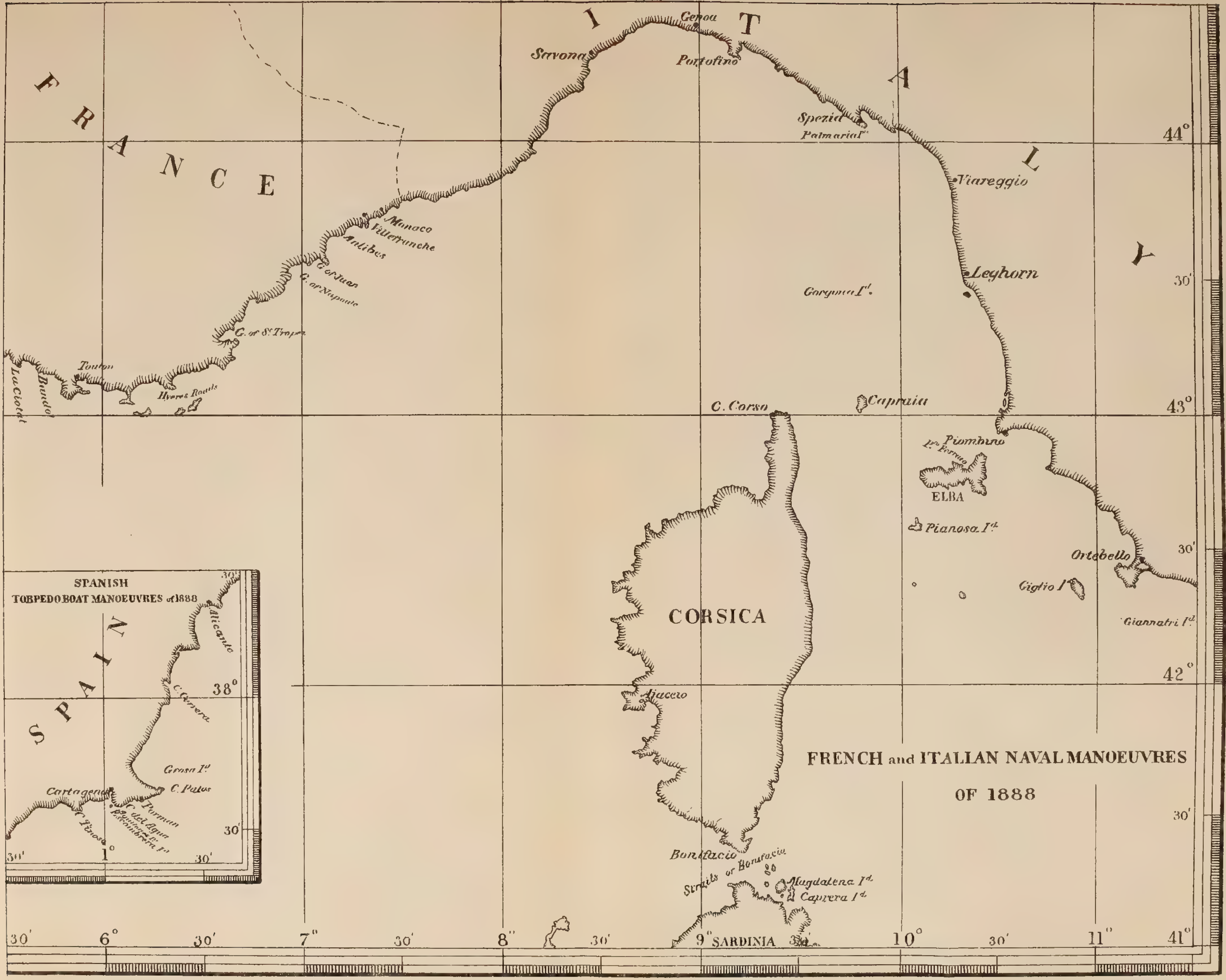
On the 5th of September the fleet disbanded. The mobilized ships went back to Toulon and the squadron of evolutions resumed its ordinary functions.

COMMENTS.

There is little to add to the few remarks which have been introduced in the narrative of the operations. This narrative is founded entirely upon newspaper statements, no official reports having been permitted to see the light; and while it is probably in the main correct, the newspaper accounts having been largely written by professional men, the uncertainties of its source should not be forgotten. An official report would probably have shown many accidents and injuries which the newspaper correspondents were not permitted to know.

The mobilization was savagely attacked by "Commandant Z," a writer in the Nouvelle Revue, but the best French writers on naval affairs

PLATE III.



FRENCH and ITALIAN NAVAL MANOEUVRES OF 1888

SPANISH TORPEDO BOAT MANOEUVRES of 1888

admitted that its results showed a very good condition of the material, and it is probable that "Commandant Z" was not influenced alone by patriotism.

It was considered that an advantage was gained by placing newly commissioned ships with others of the squadron of evolutions in the same divisions. The new captains learned their business more quickly when alongside of a vessel which had been doing naval tactics every day for months.

ITALY

The following account of the Italian naval manœuvres is taken principally from the report of Vice-Admiral Acton, under whose direction they were conducted.

SCHEME OF THE MANŒUVRES.

The manœuvres were divided into two periods:

1. One of exercises and tactical movements (preparatory).
2. One of warlike operations.

The object of the first period was to ascertain precisely, by a somewhat prolonged exercise of fleet tactics, the value of the material at hand, in order to be better prepared for the execution of the strategic themes of the second period.

It was also intended to put the flotilla of torpedo boats through a separate and independent programme of exercises, which should determine unsettled questions as to their employment and their value in time of war.

The objects of the second period, where two squadrons were opposed to each other, were to mobilize the land and maritime defenses of Spezia, and to determine the capacity of the arsenal to supply a fleet with coal and stores at the same time; *i. e.*, when its force was actively engaged in putting the fixed and mobile defenses of the arsenal and gulf into a state of readiness for service.

The problem proposed was the following:

"At a time of profound peace, a war suddenly breaks out, and hostilities are declared forty-eight hours after the first alarm. The bulk of the national squadron is at Porto Ferraio, in the island of Elba.

"A hypothetical naval division is in the Greek archipelago, and can reach the Straits of Messina thirty-six hours after the receipt of telegraphic instructions.

"Sardinia represents the enemy's country."

The hypothetical naval division was Italian, and was called the division of the Levant.

The object of the enemy was to attempt to surprise and attack Spezia, to interfere with the effective mobilization of the defenses of the Gulf, and to prevent the national squadron from employing it as a base of supplies; to dispute the passage of the division of the Levant and keep it from joining the national forces; and to raid the Italian coast, cutting railroads and telegraph lines, and destroying the signal stations.

The national squadron was to concentrate at Spezia at once, guaranty the mobilization of the defenses of that port, complete with coal and stores, and assume the offensive as hereafter indicated, and was to take measures to secure its re-enforcement by the division of the Levant.

The Italian coast subject to attack was limited to that portion between Genoa and Torre Troia (near Elba) and the Tuscan archipelago. All attempts upon the enemy's territory were forbidden, and the offensive by the Italian fleet was limited to attacks at sea off the coast.

Actions between squadrons were to cease as soon as the battle formations were defined and the first gun fired. The chase of single ships was to continue until, under the rules, a capture or escape had been effected.

The rules elaborated by the general staff and in force for several years respecting single-ship actions, actions with torpedo-boats, etc., were maintained, and to these were added others to cover the cases of actions between ships and forts or batteries.

All the defenses of the port and Gulf of Spezia, submarine, land, and mobile, were to be placed in thorough readiness for service as if in a state of war. The forts and batteries were to be connected by telegraph lines. This brought into the scheme a part of the army, the artillery manning the forts.

It will be observed that the Italian manœuvres did not include the mobilization of any ships of the fleet. These had previously been commissioned. No floating material was mobilized except the school-ships and their tenders, forming part of the permanent defenses of the port, and under the command of the Director of Submarine Defense.

THE FIRST PERIOD.

Admiral Acton had twelve ships, which he organized as follows:

First squadron: *Savoia*, *Bausan*, *Goito*, *Saetta*.

Second squadron: *Italia*, *Lepanto*, *Dandolo*, *Duilio*.

Third squadron: *San Martino*, *Colonna*, *Tripoli*, *Folgore*.

The light cruisers were given the value of battle-ships.

This fleet left Spezia on the morning of July 8 to begin the tactical exercises.

Admiral Acton proposed:

(1) To manœuvre at close distance with twelve ships, maintaining that speed ascertained to be best adapted to the secure and regular working of the machinery.

(2) To study tactical formations and decide upon the best orders for cruising and battle.

(3) To simplify changes of formation, in order that they may be ac-

complished without reduction of speed. (A greater use of oblique movements is probably here referred to.)

(4) To anchor a fleet in the most favorable formation, both from the nautical and the military point of view.

The speed maintained was from 10 to 12 knots; the distance between the ships 300 metres; the interval between squadrons sometimes 300 metres and sometimes 600 metres.

The squadron (four ships) and the division (six ships) were taken at different times as the tactical unit, to demonstrate that the character of individual movements of ships was not changed by making this unit smaller or larger.

The fleet manœuvred until the 12th, anchoring at Porto Ferraio, Civitavecchia, and Gaëta. The admiral reported a marked improvement in the skill and confidence with which captains handled their vessels.

On the 12th the fleet was organized into two divisions and the ships were sent to take the posts which had been assigned them for the exercises of the second period.

The torpedo-boats, thirty-three in number, were organized into ten groups, and at noon on the 3d of July they were ordered to make a careful examination of the coast from Torre Troia to Ventimiglia, including also the islands of the Tuscan archipelago. To each group was assigned a certain district. They were directed to ascertain the capabilities of the coast for affording shelter to torpedo-boats, and for supplying them with water and coal, and to determine lookout stations from which warning might be given of movements at sea, thus guarding against surprises. This cruise lasted five days, and the men and officers were then given a day's rest.

On the 9th the boats began their exercises of firing torpedoes. It had been the intention that each boat should launch ten torpedoes in the day-time and four at night against a moving target. Bad weather interfered with the completion of this programme, but there were one hundred and forty four launched by day, and forty by night, with generally satisfactory results.

THE SECOND PERIOD.

The National Squadron was composed of the battle-ships *Italia* (flag of Vice-Admiral Bertelli), *Lepanto*, *Dandolo* (flag of Rear-Admiral Martinez), and *Duilio;* the cruisers *Bausan* and *Etna;* the torpedo cruisers *Goito*, *Tripoli*, *Saetta*, and *Folgore;* six high-sea torpedo-boats, and eight coast-defense torpedo-boats. These latter were divided between the ports of Leghorn, Porto Ferraio, Santa Margherita, and Genoa.

There were also at Spezia, and attached to the defense of that station, one high-sea and twelve coast-defense torpedo-boats, the gun-boat *Sentinella*, four tugs, six armed launches, the school-ships and their tenders.

The Enemy's Squadron consisted of the battle-ship *San Martino* (flag of Rear-Admiral Lovera) and the cruisers *Stromboli*, *Staffetta*, and *Colonna*, and six high-sea torpedo-boats. The four ships were, under the rules, equal to any four battle-ships.

On the night of July 15 the admirals in command were notified that hostilities were imminent, and on the 18th, at 8 a. m., war was declared. The National Squadron was in the vicinity of Elba, with the *Folgore* at Porto Ferraio to bring out dispatches. The Enemy's Squadron was at Maddalena.

Admiral Bertelli telegraphed the Division of the Levant to pass the Straits of Messina, to hug the north coast of Sicily throughout its whole length, then to direct its course to the Straits of Bonifacio, and to cruise in that vicinity, awaiting the arrival of the National Squadron, and hold itself in readiness to cut off the enemy's retreat. The National Squadron proceeded towards Spezia and cruised off the port.

Admiral Lovera, commanding the Hostile Squadron, sent the *Colonna* to Stromboli to dispute the passage of the Division of the Levant, and with the remainder of his squadron left Maddalena for Genoa, passing up the west coast of Corsica to avoid the national cruisers.

Early in the morning of the 19th the *Italia*, *Goito*, and *Saetta* entered the harbor of Spezia to communicate. Admiral Bertelli received information that the enemy had appeared off Genoa and at once took his squadron north and at 6 p. m. was off Portofino.

Admiral Lovera reached Genoa at 10 a. m., passed before the port at full speed, firing upon the batteries, and sent his torpedo-boats into the port to attack shipping. (Genoa was not placed in a state of defense.) The Hostile Squadron appears then to have disappeared at sea.

July 20 the National Squadron anchored at Spezia and took in supplies of coal and water. At 11 p. m. the enemy made a demonstration against Spezia, passing between the islands of Tino and Palmaria. The batteries of Cava Castellana and Palmaria opened fire and the torpedo-boats of the defense attacked. The National Squadron at anchor rigged defense nets and employed the electric lights. The Hostile Squadron drew off with the loss of two torpedo-boats; and the *Folgore*, of the National Squadron, was also declared out of action. Admiral Lovera sent torpedo-boats to attack the islands of Gorgona and Capraia, and cut their telegraph cables.

On the 21st the National Squadron, with the exception of the *Goito*, went to sea at 6 p. m. and cruised off Spezia all night.

At midnight the enemy's vessel *San Martino* captured the station of San Vincenzo and cut the Maremma railway. The *Stromboli* simulated the destruction of bridges near Gavi-Liguria, and the *Staffetta* also made a raid on the coast. The *San Martino* and *Stromboli* were three hours on the coast and were not disturbed. The *Staffetta* was attacked by coast-defense torpedo-boats from Genoa.

On the 22d the National Squadron finished coaling at Spezia, and at

6 p. m. got under way and cruised along the coast to the south to join the Division of the Levant, which had been telegraphed the night before to rendezvous near Piombino.

Admiral Acton, in the *Savoia*, left Spezia to make a rapid tour of the sphere of operations, to ascertain the vigilance of the semaphore stations and the progress of the manœuvres.

July 23, 6 a. m., the Hostile Squadron returned to Maddalena to coal.

At 5 a. m., July 24, Admiral Acton entered San Stefano Roads, Island of Maddalena, and found the Hostile Squadron coaling and repairing, with fires banked. At the same time the National Squadron appeared at the entrance to the Roads, preparing to attack with the ram. This being contrary to the scheme of the manœuvres, Admiral Acton ordered the attack to cease, and sent the National Squadron to sea in the direction of Spezia. It arrived at that port on the morning of the 25th again completed with coal, and executed light repairs.

Admiral Lovera left Maddalena at 2 a. m. July 25, passed up the east coast of Corsica, and reached Gorgona in the evening, and again attacked that island to cut the submarine cable.

On the nights of the 25th and 26th he sent his torpedo-boats to attempt attacks on Spezia.

On the 27th, at daybreak, the two squadrons had an engagement off Gorgona. Admiral Bertelli returned on the 28th to Spezia. Admiral Lovera repeated his movement before Genoa on that day, and on the 29th attacked Spezia, and was received with a violent cannonade, six hundred shots being fired in a little more than thirty minutes.

The squadrons returned to Porto Ferraio and Maddalena, and the manœuvres came to an end.

COMMENTS.

The resources of Spezia appear to have been quite equal to the demands made upon them. On the 20th July the fleet took in 2,286 tons of coal and 463 tons of water in seven hours, and at all other times the supplies were prompt and satisfactory.

The *Esercito*, an Italian newspaper, is quoted to the effect that many of the ships suffered material injury to their steam machinery. It was said that the *Savoia*, *Lepanto*, *Folgore*, *Dandolo*, *Colonna*, *Staffetta*, and *Italia* would need twelve days' repairs, the *Bausan* thirty days, the *Goito* twenty-two, the *Etna* nineteen, the *San Martino* twenty-two, the *Stromboli* and thirteen torpedo-boats ten days; that the *Duilio*, *Tripoli*, and *Saetta*, and seventeen torpedo-boats were in good condition and ready at the end of the manœuvres for further service.

It would not be wise to base an opinion as to the value of the manœuvres upon the scanty information at hand. Admiral Acton said they were rich in practical results, but he did not indicate the lessons which he considered them to have taught.

SPAIN.

TORPEDO-BOAT MANŒUVRES.

Nine torpedo boats and the torpedo-boat catcher *Destructor*, belonging to the departments of Cadiz, Ferrol, and Cartagena, were ordered to assemble at the latter port for exercise and manœuvres in April, May, and June. Cartagena was selected for the rendezvous because it has large torpedo supplies; also because the Mediterranean is better adapted for torpedo-boat manœuvres than the Atlantic, and there is an excellent place for target firing near Cape Palos. The season was selected with a view to having fine weather and at the same time avoiding the great heats of summer, which are exceedingly trying to the crews of torpedo boats on account of the unusually high temperature experienced in those vessels.

Soon after leaving Ferrol on April 5 the crown sheet of the *Habana*, a Thornycroft boat of 67 tons displacement, collapsed, and the steam and hot water killed four men and badly scalded a fifth. There was a fresh breeze and considerable sea at the time.

The *Ariete* (125 tons) endeavored to take the disabled boat in tow, but failed after losing her steel tow-ropes and damaging her machinery. The *Destructor* (386 tons) came to the rescue and after five hours' work succeeded with great difficulty in taking the *Habana* in tow.

This accident reduced the flotilla to eight boats, and of these the *Retamosa* reached Cartagena with a blade of her propeller bent, and the *Ariete* had a boiler disabled; but, as without this boiler, she was able to steam 18.4 knots, she was permitted to take part in the exercises.

The following table is descriptive of the *Destructor* and the torpedo boats:

Name.	Builder.	Date of construction.	Length.	Breadth.	Mean draught.	Displacement.	Maximum I. H. P.	Speed at 2 and 3 hours trials.
			Feet.	*Feet.*	*Feet.*	*Tons.*		
Destructor	Thompson	1886	192.7	25	6.88	386	3,800	22.56
Ariete	Thornycroft	1887	147.5	14.5	4.48	125	1,626	26.3
Rayo	do	1887	147.5	14.5	4.48	125	1,626	26.3
Halcon	Yarrow	1887	135	13.8	3.93	100	1,626	23.04
Azor	do	1887	135	13.8	3.93	100	1,626	23.04
Barcelo	Normand	1886	127	11	....	65	....	19.5
Retamosa	Yarrow	1886	117	12.5	3.28	69.8	650	20.5
Ordoñez	Thornycroft	1886	117	12.5	3.44	65.8	666	20.16
Acevedo	do	1886	117	12.5	3.44	65.8	666	20.16

The *Destructor*, owing to her draft, was liable to torpedo attack.

The torpedo boats were all fitted with electric search-lights of about 7,500 candle power.

The *Ariete*, *Rayo*, *Azor*, and *Halcon* were each intended to carry three or four 42-millimetre Nordenfelt rapid-fire guns, but had not been equipped with them. The *Ordoñez*, *Acevedo*, *Barcelo*, and *Retamosa* each carried two Nordenfelt 4-barrelled 1-inch machine guns. All the boats were supplied with small arms.

On May 16th the last boat of the flotilla reached Cartagena.

The torpedo boats were formed in one division, the tactical unit adopted being a group of three boats, and the royal order particularly specified that boats most similar to one another should be grouped together. Captain Bermejo, Royal Spanish Navy, Director of the Torpedo School, was placed in command.

The following programme was laid down:

First week.—Torpedo target practice; boats and target stationary.

Second week.—Torpedo target practice; boats moving, target stationary.

Third week.—Torpedo target practice; boats and target both moving. Measurement of speed of boats. Determination of tactical circles at full and half speeds. In making speed measurements the corresponding number of revolutions was to be tabulated for future convenience.

Fourth week.—Attack by groups or tactical units upon moving targets. Trial of pumps and ejectors.

Fifth week.—Night sorties. Reconnoitring for ships and attacking them.

Sixth and seventh weeks.—Comparative speed trials, the boats to be as nearly as possible under equal conditions, with boilers and engines in perfect order; the coal for each boat to be selected by its commanding officer; the draft to be the same as at the acceptance trials of two, three, or four hours' duration. These comparative speed trials were to take place over a carefully marked course.

Race from Cartagena to Alicante.

Evolutions about six buoys placed in a line, to determine the steering and turning qualities.

Target firing with rapid-fire guns, machine guns, and small arms, one of the targets to represent a section of a torpedo boat, and to carry the air-chamber of a torpedo charged to 100 atmospheres and a fighting torpedo head. A group of boats to concentrate its fire upon this target for a given time, to determine the number of hits and the destructive effect of the arms carried by torpedo boats upon the hulls, and upon the air-chambers and loaded heads of torpedoes. This exercise was to be had at night, illuminating the target by the electric projectors of the firing boats, and at a range of from 500 to 600 metres.

The torpedo target practice and the target practice with rapid-fire guns, machine guns, and small arms is described and commented upon in the Notes on Torpedo boats in this volume (pp. 447–451).

The utility of the electric search-light for torpedo-boat work was very thoroughly tested, and the result of these trials will be its abolition from the equipment of torpedo boats in the Spanish Navy. It is valueless in a seaway on account of the motion of the boat, which renders it almost impossible to focus the light upon any object and maintain it there; and it serves at such a time only to indicate the position of a torpodo boat to its enemies. At all times it was so near the water that it illuminated a large expanse of the sea's surface, the confused reflection making it extremely difficult to distinguish objects in the illuminated arc, and quite impossible to see anything outside of it.

In the steering and evolutionary trials the smallest tactical diameters were obtained with slow speeds of 8 to 10 knots. Only a few particulars were given. The diameter was diminished by using both bow and stern rudders, but the speed was materially lessened. The extreme helm angles were from 20° to 25°. The boats did not steer well going astern.

On June 5 seven of the boats were run in two groups from Escombrera Island to Alicante, 68 knots, to test their sea speed under service conditions. The first group consisted of the *Barcelo*, *Ordoñez*, *Acevedo*, and *Ariete*. The second group consisted of the *Rayo*, *Azor*, and *Halcon*, and started 35 minutes after the first. The run from Escombrera to Cape Palos was against a fresh breeze and rough sea which broke over the bows of the boats and against their funnels. From Cape Palos to Alicante the wind was light and the sea calm. The *Barcelo*, a Normand boat, and the smallest of the flotilla, won the race, making a mean speed of 19.7 knots, and a speed between Cape Palos and Alicante of 20.4. The *Barcelo's* original trial speed was 19.5 knots. Every other boat in the flotilla had a record of greater original trial speed than this, the *Rayo's* having been 26.3.

The *Ariete*, sister boat to the *Rayo*, ran under one boiler only.

Several experiments were made to determine the degree of success with which a ship could be discovered and approached by torpedo boats in the darkness, especially when the latter came out under cover of the deep shadows made by high land. The ship in these instances was represented sometimes by the *Destructor* and sometimes by one of the larger torpedo boats. The result of these experiments showed that it is difficult to detect the approach of torpedo boats with high land behind them, and that for a ship to run down a coast protected by torpedo boats is an operation of considerable danger, and should not be undertaken. The disadvantages of using an electric projector mounted near the surface of the water have already been commented upon.*

The chance of discovering the torpedo boats from the deck of a cruiser or battle ship would probably be much better.

---

* This refers only to the use of electric projectors in torpedo boats, where they are practically at the surface of the water. Repeated experiments have shown that on vessels of ordinary size the search light is most serviceable when placed relatively low.

UNITED STATES.

OPERATIONS OF THE NAVAL BRIGADE.

The naval brigade of the North Atlantic Squadron was landed for instruction and exercise from April 11 to April 19 at Camp Osceola on Magnolia Bluff, near Pensacola, Fla.

Commander O. F. Heyerman was placed in command of the brigade and the following memorandum, transmitted to him by Rear Admiral Luce, commanding the North Atlantic Squadron, indicates the objects which the camp was expected to accomplish:

"The camp of instruction has been established for the purpose of affording an opportunity for the officers and enlisted men of the brigade to practice those duties on shore which can not conveniently be carried on afloat.

"Company drills, including skirmish drill, should be as frequent as possible. After a few drills, target firing, principally by companies advancing and retreating in skirmish line, should be carried on, using the eighteen skirmish targets now on board the *Richmond.*

"Men entirely unused to handling a rifle to be put in seperate squads for special instruction.

"Skirmish firing to be carried on according to Army regulations, and the records kept in the same way.

"Each man in the brigade to fire while on shore from 30 to 40 rounds at least.

"A range of 1,000 yards to be established for 3-inch rifle, and one of 500 to 700 yards for Gatlings. The practice with the 3-inch rifle to include curved firing with reduced charges, the target being screened from the gunners. A careful record to be kept of this as well as of all other practice.

"All firing to be carried out in accordance with the drill.

"The drill as laid down in the books is on no account to be dispensed with; otherwise its good and bad points will not be revealed.

"It is desirable to have a few simple war problems drawn up and carried out by opposing forces selected from the brigade. Accounts of all movements to be fully written out by the engineer-in-chief of the brigade. Full reports of the work done at the camp, accompanied by reports of brigade staff and officers commanding battalions, will be called for on returning to the ships."

The camp was laid out before landing. The force was encamped in column of divisions, 6 feet between tents, streets 15 feet wide. Thirty feet to the rear was the line of company kitchens. Sixty feet behind the company kitchens were the tents of the company and section officers, with their kitchens also 30 feet to the rear of their tents. Sixty feet behind the officers' kitchen was the line of tents of battalion commanders, each in rear of the centre of his battalion. Thirty feet behind the battalion commanders was the non-commissioned staff, and 100 feet farther to the rear the brigade commander and his staff. The ordnance tents were on a line with the headquarter tents and 40 yards to the left. Latrines on the flanks to leeward. The hospital and commissary were in a building on the weather side of the camp, and the medical officers were quartered in a tent near by. Water was supplied from a 5,000-gallon tank which was kept filled by a steam-pump.

The parade was in front of the color line.

The brigade was landed at 1 p. m. by battalions. Tents were pitched, sentinels posted, and the usual camp routine established. The force consisted of 44 officers and 601 men—a total of 645, about 63 per cent. of the complement of the squadron. Of this force 121 were marines. The marines were detailed as orderlies, but all sentry and outpost duty was performed by blue jackets.

The command was entirely under cover. Some of the tents came from the marine post at the Pensacola Navy-Yard and others were borrowed from the Army post at Barrancas. The guard-tent was made from a ship's awning and side-curtains.

By 5.30 p. m. the camp was fully established and the following daily routine went into effect:

Daily camp routine.

Time.	Routine.	Time.	Routine.
A. M.		*P. M.*	
4.00	Cook's call.	1.00	Target practice, small arms and artillery.
4.50	Call trumpeters of guard.	1.30	Serve out provisions.
5.00	Assembly of trumpeters.	3.00	Drill call; assembly; adjutant's call; company and section drill; battalion drill.
5.05	Marches; drums and bugle through camp.	4.30	Recall from drill and target practice.
5.15	Reveille; assembly; coffee and bath.	4.50	Drill call; assembly.
6.30	Mess call; breakfast.	5.00	Battalions form.
7.15	Sick call; fatigue call; police call.	5.10	Brigade form; dress parade.
8.15	Assembly of guard detail, guard mounting.	5.30	Mess call; supper; sundown; retreat.
9.00	Drill call; assembly; adjutant's call; company and section drill; target practice, small arms and artillery; battalion drill.	8.45	Assembly of trumpeters.
10.30	Recall from drill.	8.50	Drum and bugles; march through camp.
11.30	Recall from target practice.	9.00	Tattoo; assembly.
12.00	Mess call; dinner.	9.15	Taps by drums, then bugles; out lights.

Saturdays: No drill during the afternoon.

Sundays: 9 A. M., assembly; adjutant's call; battalions form; inspection of brigade by brigade commander.

The exercises of greatest value were the target firing with different arms. That with the 3-inch B. L. R. included direct and curved fire. The former comprised a series of shots at 1,000 yards at a canvas target

4 feet high and 20 feet long, and a series of shots over the water at unknown distances up to 1,700 yards in order to give instruction in quickly picking up the range by the fall of the shot. The curved fire was at a concealed target 1,200 yards distant, the gun being pointed by range stakes. The charge was 3½ ounces, the elevation 13° to 15°. The firing was slow and rather inaccurate and showed the necessity of more practice. The fuses were found to be defective. Three thousand rounds were fired from a Gatling gun at 400 and 600 yard ranges and at targets at unknown and varying distances over water to exercise the men in picking up a range. The target was 4 feet high and 20 feet long. At 400 yards the hits were 28 per cent.; at 600 yards the hits were 14 per cent. Only one jam occurred and that from pulling off the head of a cartridge.

The two Hotchkiss revolver cannons fired about 100 rounds each. Great difficulty was experienced in getting the men to fire these guns at a proper speed. The guns and ammunition worked well, with the exception that a number of the fuses failed to act.

The Squadron Inspector of Target Practice, from whose report this information is taken, thinks the one-pounder rapid-fire a better gun for field purposes than the revolver cannon. The gain in lightness would be very great and the loss of celerity in fire inconsiderable.

Each first and second gun captain was exercised in firing a rifle from an unstable platform—a boat anchored 150 yards off shore at an army B target set up on shore. It was also attempted to exercise the same men in firing at 1,000 yards range on shore at an army C target; but this was so evidently beyond their skill that it was given up.

Company firing at 18 skirmish targets at 200 and 300 yards range was had, each man firing 30 shots. Of the 18 figures, 6 were lying down, 6 kneeling, and 6 erect. The percentage of hits was very low—from 0.7 to 2 per cent.

The artillery had pistol practice at 20, 30, and 40 yards.

The Inspector of Target Practice in reporting the results of these exercises makes several suggestions. He found the men spirited and zealous and very fond of the practice, but needing instruction and better facilities and specially lacking in "fire discipline" on the skirmish line and in sham battle. In the latter instance several men were badly burnt by powder because the firing could not be stopped. Non-commissioned officers did not sufficiently recognize their duties and obligations to assist in enforcing the commands received from the captains of companies. He recommends simplicity in artillery movements and a closer tactical connection between the artillery and the infantry of an ordinary naval force. He recommends, also, that each man should have his own rifle and be responsible for its cleanliness and good condition, and should be instructed in dismounting and assembling it.

On the night of the 15th, after taps, an alarm was sounded, and the camp was placed in a state of defense in less than three minutes. Sentinels were doubled, skirmishers sent out in front, both flanks, and rear with a reserve for each line, the artillery was placed in position, and the main body was assembed on the parade.

A war problem was devised and carried out on the 17th. It consisted of an attempt to cut off and capture at a bridge the rear guard of a force whose main body had crossed the bridge; and the principal points to be brought out were the management of advance guards and flankers while on the march, and the conduct of reconnaissances for obtaining information.

The spirit, health, and conduct of the men were excellent throughout, and their improvement in camp duties and drills demonstrated the value of the exercise. Quartermaster's, ordnance, commissary, and hospital arrangements were efficient and satisfactory. On April 19th the camp was broken and the several battalions returned to their ships.

Plate 1.

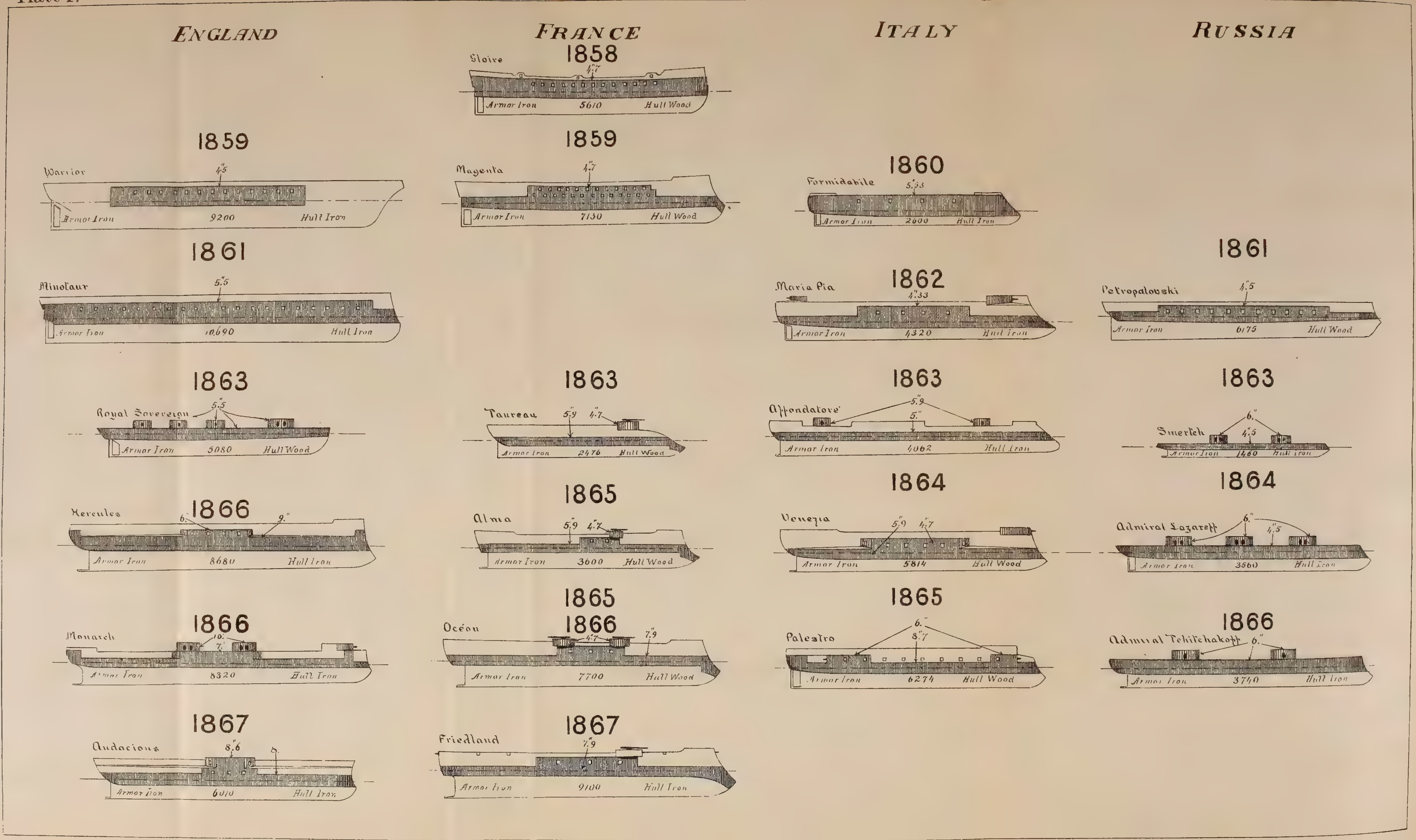

ENGLAND
1859
Warrior
4".5
Armor Iron
9200
Hull Iron
1861
Minotaur
5".5
Armor Iron
10,690
Hull Iron
1863
Royal Sovereign
5".5
Armor Iron
5080
Hull Wood
1866
Hercules
6."
9."
Armor Iron
8680
Hull Iron
1866
Monarch
10."
7."
Armor Iron
8320
Hull Iron
1867
Audacious
8".6
Armor Iron
6010
Hull Iron
FRANCE
1858
Gloire
4".7
Armor Iron
5610
Hull Wood
1859
Magenta
4".7
Armor Iron
7130
Hull Wood
1863
Taureau
5".9
4".7
Armor Iron
2476
Hull Wood
1865
Alma
5".9
4".7
Armor Iron
3600
Hull Wood
1865
1866
Océan
4".7
7".9
Armor Iron
7700
Hull Wood
1867
Friedland
7".9
Armor Iron
9100
Hull Iron
ITALY
1860
Formidabile
5".53
Armor Iron
2600
Hull Iron
1862
Maria Pia
4".33
Armor Iron
4320
Hull Iron
1863
Affondatore
5".9
5."
Armor Iron
4062
Hull Iron
1864
Venezia
5".9
4".7
Armor Iron
5814
Hull Wood
1865
Palestro
6."
8".7
Armor Iron
6274
Hull Wood
RUSSIA
1861
Petropalovski
4".5
Armor Iron
6175
Hull Wood
1863
Smerlch
6."
4".5
Armor Iron
1460
Hull Iron
1864
Admiral Lazareff
6."
4".5
Armor Iron
3560
Hull Iron
1866
Admiral Tchitchakoff
6."
Armor Iron
3740
Hull Iron

PLATE II.

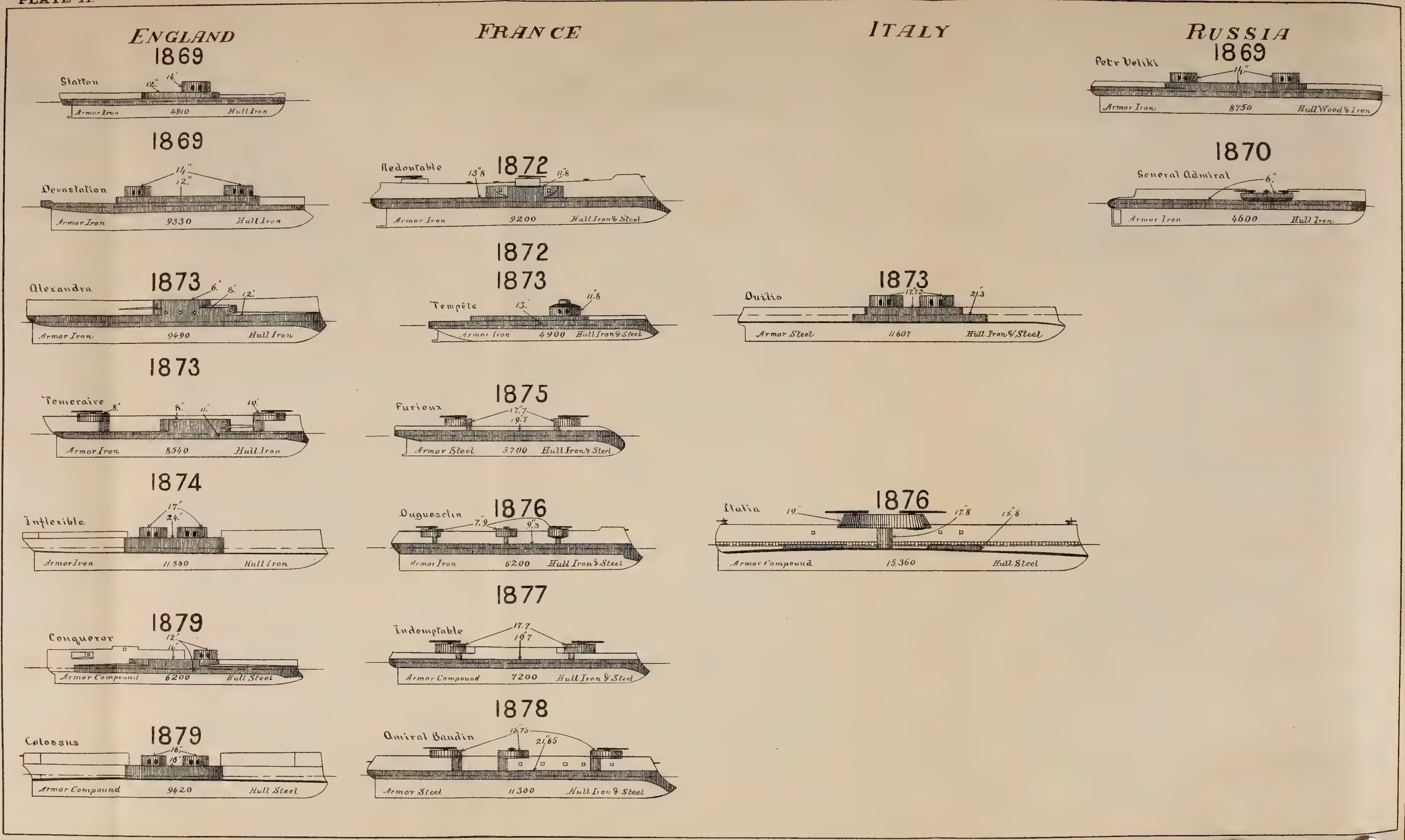
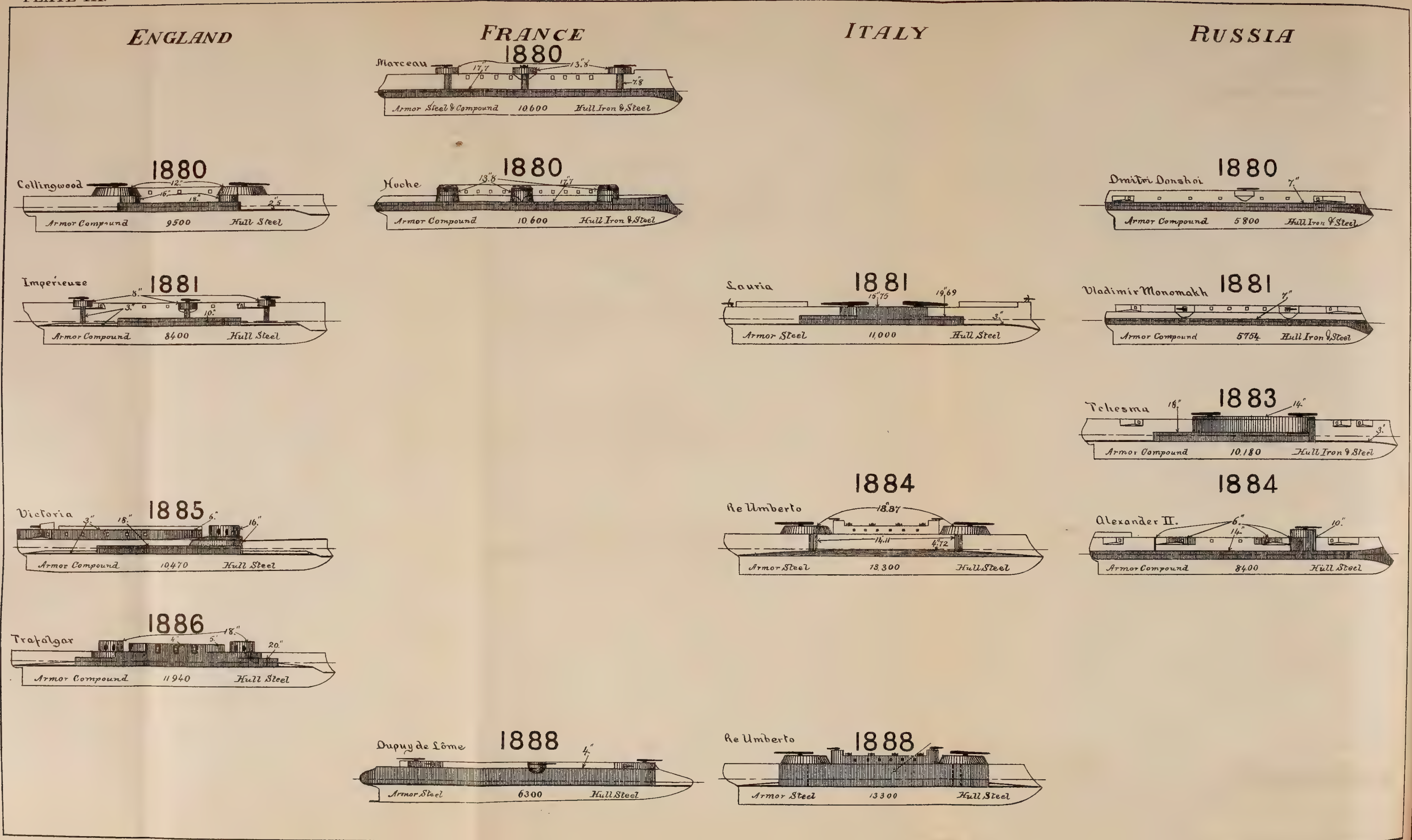

ENGLAND
1869
Glatton
12"
14"
Armor Iron
4910
Hull Iron
1869
Devastation
14"
12"
Armor Iron
9330
Hull Iron
1873
Alexandra
6"
8"
12"
Armor Iron
9490
Hull Iron
1873
Temeraire
8"
8"
11"
10"
Armor Iron
8540
Hull Iron
1874
Inflexible
17"
24"
Armor Iron
11880
Hull Iron
1879
Conqueror
12"
14"
Armor Compound
6200
Hull Steel
1879
Colossus
16"
18"
Armor Compound
9420
Hull Steel
FRANCE
Redoutable
1872
13"8
11"8
Armor Iron
9200
Hull Iron & Steel
1872
1873
Tempête
13"
11"8
Armor Iron
4900
Hull Iron & Steel
1875
Furieux
17"7
19"7
Armor Steel
5700
Hull Iron & Steel
Duguesclin
1876
7"9
9"5
Armor Iron
6200
Hull Iron & Steel
1877
Indomptable
17.7
19"7
Armor Compound
7200
Hull Iron & Steel
1878
Amiral Baudin
15"75
21"65
Armor Steel
11300
Hull Iron & Steel
ITALY
1873
Duilio
17"72
21"3
Armor Steel
11607
Hull Iron & Steel
1876
Italia
19"
17"8
15"8
Armor Compound
15,360
Hull Steel
RUSSIA
1869
Petr Veliki
14"
Armor Iron
8750
Hull Wood & Iron
1870
General Admiral
6"
Armor Iron
4600
Hull Iron

PLATE III.


ENGLAND
1880
Collingwood
12."
16."
18."
2.5"
Armor Compound
9500
Hull Steel
1881
Imperieuse
8."
3."
10."
Armor Compound
8400
Hull Steel
1885
Victoria
3."
18."
6."
16."
Armor Compound
10,470
Hull Steel
1886
Trafalgar
18."
4"
5."
20."
Armor Compound
11940
Hull Steel
FRANCE
1880
Marceau
17.7"
13.8"
7.8"
Armor Steel & Compound
10.600
Hull Iron & Steel
1880
Hoche
13.8"
17.7"
Armor Compound
10,600
Hull Iron & Steel
1888
Dupuy de Lôme
4"
Armor Steel
6300
Hull Steel
ITALY
1881
Lauria
15.75"
19.69"
3."
Armor Steel
11,000
Hull Steel
1884
Re Umberto
18.87"
14.11"
4.72"
Armor Steel
13,300
Hull Steel
Re Umberto
1888
Armor Steel
13300
Hull Steel
RUSSIA
1880
Dmitri Donskoi
7."
Armor Compound
5800
Hull Iron & Steel
1881
Vladimir Monomakh
7."
Armor Compound
5754
Hull Iron & Steel
1883
Tchesma
18."
14."
3."
Armor Compound
10,180
Hull Iron & Steel
1884
Alexander II.
6."
14."
10."
Armor Compound
8400
Hull Steel

III.

DISTRIBUTION OF ARMOR.

[It was the original intention to present the first part of this article in another form, but after its preparation extremely valuable papers upon armor distribution were published in England and its scope changed to include the following:

1. A graphic history of armor protection and distribution on war vessels, by Lieut. F. Singer, U. S. Navy.
2. A paper presented to the British Parliament February, 1889, relating to the designs for proposed battle-ships.
3. A paper on the designs of the new battle-ships, read before the Institution of Naval Architects, in England, by Mr. W. H. White, Director of Naval Construction, in April, 1889.
4. Extracts from a paper on protection of buoyancy and the stability of ships, read before the Institution of Naval Architects by Sir Nathaniel Barnaby, late Director of Naval Construction, April, 1889.
5. An abstract of a paper entitled, "Uno Sguardo all' Avenir Navale," by Admiral Albini, late Director of Italian Ordnance, 1888.

The article therefore presents a graphic résumé of the changes which have taken place in the distribution of armor since 1858; the latest views of the British Admiralty upon the designs for battle-ships; an interesting paper upon the protection of ships' stability and buoyancy, together with the somewhat advanced and bold views of an officer of the Italian navy, a service which has been so conspicuous and unconventional in the building of its fleet.—Ed.]

1.

A GRAPHIC HISTORY OF ARMOR PROTECTION AND DISTRIBUTION ON WAR VESSELS.

By Lieut. F. Singer, U. S. Navy.

In the accompanying plates it has been the endeavor to present graphically the various phases in the application of armor (iron, compound, or steel) since its first employment on vessels.

A few words of explanation are appended.

The ships of the principal naval powers only are shown and are arranged in chronological order of date of design; consequently the first of each type is given rather than later and improved vessels of such type.

As the distribution of armor is so greatly dependent on the gun positions, the arrangements of batteries are also indicated.

For the sake of clearness, only the greatest thickness in inches of armor on belts and gun positions is noted. Under each figure the vessel's displacement, and the material of the hull and of armor are shown.

The figures on Plate I illustrate the first era of armor protection. To the French belongs the credit of initiating its employment, and to their distinguished constructing engineer, Dupuy de Lôme, they are indebted for the ideas practically carried out in the *Gloire*, laid down in March, 1858, and launched in November, 1859. The protection was designed to resist the effect of shell fire, and a complete layer of comparatively thin iron over the wooden hull was sufficient to resist penetration from the rifled guns of the period.

The English followed by ordering the *Warrior* in May, 1859, a vessel with protection less extensive. They were far-sighted in building the hulls of their new armored vessels of iron, and thereby prolonging their lives; so to-day many can be brought to meet the new conditions of resisting detonating-shell fire.

The Italians ordered in 1860 two completely-armored cruisers in France, the *Terribile* and *Formidabile*, French types, hulls and armor of iron.

The order for the first Spanish ironclad was given in the same year—iron broadside armor on a wooden hull.

In the latter part of 1861 the Russians changed the plans of the wooden frigate *Petropaulovsk*, then building, and gave her a complete water-line belt and casemate of iron.

In this year the *Monitor* and the *New Ironsides* were ordered in the United States, the latter of the broadside type. The effect of the action between the *Monitor* and *Merrimac* in 1862 is shown by the class of vessels ordered in Europe in 1863 and in Russian construction for succeeding years.

The Germans ordered, from Samuda Bros., England, their first armored vessel in 1863, the *Arminius*, of the *Monitor* type, with Captain Cole's turrets.

It will be noted that all vessels shown on Plate I have the complete water-line belt, the increase in thickness from 4.5 to over 8 inches is given at the expense of area in battery armor, the English concentrating in a central casemate; the French protecting the smaller guns in the same manner, but placing the heavy guns in barbettes with larger firing arcs. The Italians have separate protected gun positions.

Plate II shows the turret era in the English service, the *Alexandra* being the last central casemate ship. As the value of the heavy guns increased, the secondary battery was sacrificed in order to give these heavy guns commanding arcs of fire. The increase in the thickness of the armor for gun positions and water-line protection led to shortening the belts, protecting only the vitals of the ship, and resorting to armored-deck protection and water-tight compartments for the ends.

The French continue to adhere to the complete water-line belt, but at the expense of gun protection. The heavy guns are well above water in armored barbettes with ammunition tubes, giving protection to the carriage and to the loading of the gun. If the high-explosive shell is a success, it is easy to see the danger of having the guns dismounted by explosions below the barbettes. To minimize the chances of destruction of the whole primary battery, these heavy guns are placed in as widely separated positions as possible; the secondary batteries, comprising a number of 14 to 16-centimetre guns, are carried on a lower deck and are unprotected.

The Italians have given up their separated gun positions; in the *Duilio* and *Dandolo* they have two turrets on a central citadel, and dispense with a secondary battery. The water-line belt is shortened very much and the ends have a protective deck; even this short belt is given up in the *Italia* and *Lepanto*, where the floating power is dependent on a cellular raft over a protective deck; the primary battery, four 16.97-inch, is carried in an armored central barbette, with an armored ammunition tube, the system having the same objections as noted in similar French types. The secondary battery as designed was sixteen 6-inch, but only eight are carried.

The Italians were the first to perceive the necessity of a large displacement, in order to properly fill the requirements of a first-class battle-ship in regard to offense, defense, speed, and cruising power; *i. e.*, to carry the necessary weights of guns, armor, machinery, and coal.

The Russians, after building the *Petr Veliki*, of the *Devastation* type, show French influence in 1870, by adopting the complete belt and barbettes, followed on Plate III, by vessels somewhat similar to the *Alma* and *Ocean* types in armor and gun distribution.

After this, however, a reaction towards gun-protection is shown in the *Tchesma* class, where the six heavy guns, still in barbette, are mounted on disappearing carriages in a triangular central redoubt. The complete water-line belt is given up, and the ends are deck-protected. In some of their new constructions on the Black Sea they return to turrets, while on the Baltic the type represented by the *Alexander II* is the favorite. To meet the new demands for resistance to detonating shell, the isolated armor on gun-positions is reduced in thickness and spread over a larger and continuous area.

The Russians so far have not gone to extremes in the size of their heavy guns on shipboard; their largest calibre is 12-inch, but these are supported by guns of 9-inch and 6-inch calibre.

The Italians, in the *Lauria* class, revert to the partial belt, with armored decks for water-line protection, and a strong central redoubt, carrying the heavy guns in barbette. The secondary battery is unimportant.

Their latest types are of the *Re Umberto* class, shown first as laid down; the weights of the original armor and fuel are to be reduced, and this reduction is to be put into side-armor protection against detonating shell and projectiles from R. F. guns.

The second figure gives a general idea of the armor distribution; its character and thickness are not yet determined, but will be governed by the weights available and the amount of fuel to be carried. The floating power is maintained by a very effective cellular protection, which extends down to the bilge, forming practically a triple hull. This is the first departure from the net, to hull-defense against torpedoes.

In looking at the French ships on this plate we still find the complete water-line belt. A change in gun-protection, however, is noted in the *Hoche*, a sister ship to the *Marceau*, in which the barbette with its light shield is changed to a completely covered barbette or modified turret. Each of the four heavy guns is carried in a separate armored position over an armored redoubt; an arrangement of the primary battery rather costly in weight of armor. In their new vessels the guns are to be mounted in pairs in end turrets. The latest design, the *Tréhouart*, of about 10,500 tons, laid down at Lorient, is to be a modified *Furieux* type (Plate II), with turrets instead of barbettes.

The last figure represents a modern *Gloire* (Plate I). After thirty years the appearance of the detonating shell presents the same problem as that solved by the designer of that vessel, and this new completely-armored cruiser is very aptly named *Dupuy de Lôme*.

The next step is, as before, a reduction of area. The new French armored cruisers to be built have a battery disposition like the *Charleston*, and the armor (10 centimetres) extends up the battery deck. The guns are in modified turrets or closed barbettes.

The English started in this decade by building barbette ships with armored ammunition-tubes, but provided no protection immediately below the barbettes. There is a protective deck, but the armor belt for water-line defense, though thick, is very short. The typical ship was followed by five of the "*Admiral* class," somewhat enlarged *Collingwoods*. These vessels carry a secondary battery of six 6-inch guns. French influence is shown by the battery distribution and its protection in the *Impérieuse* and *Warspite*.

The *Trafalgar* and *Nile* present a superior type of battle-ship. Most demands are well met, but the secondary battery is somewhat weak. It was originally designed to be composed of eight 5-inch guns in broadside without any protection, but was changed to six 4.72-inch R. F. guns behind four inches of armor.

The latest designs of English battle-ships (Plates V and VII) show modifications of the *Trafalgar* and *Collingwood*. The irresistible logic of events had forced the displacement above 14,000 tons; the water-line defense is of the same character as on the *Trafalgar*, the maximum thickness somewhat reduced; but to make room for a larger secondary battery, the heavy-gun positions are moved farther apart, and this compelled separate redoubts under each pair of guns, instead of the *Trafalgar's* central citadel. The end protection for the secondary battery of ten 6-inch B. L. is the same as in the *Trafalgar*, and a 5-inch steel belt is run between the redoubts, thereby giving protection against detonating shell beneath four of the ten guns. There is no armor abreast the secondary battery on either of the two decks, but each gun is protected by a separate closed shield or turret.

A reference to the figures on the three plates will show the changes in the material of the armor from iron to compound and steel. It will be noticed that few, if any, armored vessels with complete or partial water-line belts have these of sufficient depth to give proper protection when rolling; this defect is minimized, of course, in the large types of from 13,000 to 15,000 tons displacement that do not roll appreciably in any seaway that permits ordinary vessels to work their guns.

Another point is the incomplete protection given to the chase of the heavy and important guns, even against light projectiles from R. F. guns which can disable them quite easily, as experiment has shown.* In the original monitors the turrets completely inclosed the guns except when ready to fire; in the *Temeraire* (Plate II) the short barbette guns presented no difficulty to the use of a disappearing mount. With the introduction of the long, high-powered guns the protection was not extended, and is complete only for the carriages and loading arrangements, though the Russians in the *Tchesma* class (Plate III) are enabled to have a disappearing mount† for the 12-inch barbette guns by reducing their length from 35 to 30 calibres, a sacrifice pretty certain to be balanced by additional chance of life to the guns in action. An ammunition supply, as used in the *Miantonomoh*, or in the *Terror* (p. 346, No. VII), which permits the loading of a pair of guns while pointing at the enemy, thus reducing their size as a target, seems to be the best arrangement for turret guns.

---

* See page 384.

† See Plate 5, Chapter IV.

A design for gun position and protection in small vessels, called the "Barrow battery," prepared by the Naval Construction and Armament Company, of Barrow, England, assisted by Sir J. Whitworth and Company, and on the advice of Sir N. Barnaby, is shown on Plate VIII.

A barbette with 8 to 9-inch armor is centrally placed and built around the smoke-pipe, which is surrounded by non-conducting material and air spaces. The guns with their dome shield revolve around this smoke-pipe and the conning and sighting platform placed against its outer casing.

This arrangement gives an all-around fire in a mastless vessel and was designed to enhance the fighting value of small and cheap ships; all the arguments put forth by the company are in favor of such a type, and are practically the same as were advanced some years ago by the extreme advocates of the torpedo-boat.

The guns in the original design of a 3,200-ton battle-ship are two 9.2-inch B. L., 15 feet above L. W. L.; their complete circle of fire precludes the idea of a secondary battery of more rapidly firing guns, unless the ship is large enough to have two battery decks. In the design the four 6-pounder and four 3-pounder R. F. G. are only about 8 feet above the load water-line. The estimated speed of the vessel is 17 knots over the measured mile.

The water line protection consists of a cellular raft on a protective deck, the cells to be filled with a new water-excluding substance (woodite), which can be fitted in any vessel.

A report of the action taken with regard to the preparation of designs for first-class battle-ships submitted to the British Parliament is reprinted, as embodying much information of value to naval officers.

Since these plates were prepared the valuable papers read by Mr. W. H. White and Sir N. Barnaby before the Institution of Naval Architects have come to hand and extracts are appended; attention is drawn to Plate IX accompanying the latter paper, showing the effect between decks of detonating 80 pounds of gun-cotton, and which invites another examination of the ship illustrations, especially of the barbette types without armored redoubts or citadels below the guns.

So far, however, detonating shell have not been able to keep intact long enough to penetrate any but the lightest armor, the English meeting them with 5 inches and the French with but 4 inches of steel side armor, while even in unarmored cruisers the guns' shields or turrets are not over 4 to 4.5 inches thick.

2.

PAPER PRESENTED TO BRITISH PARLIAMENT FEBRUARY, 1889, RELATING TO DESIGNS FOR PROPOSED BATTLE-SHIPS.

ALTERNATIVE DESIGNS FOR FIRST-CLASS BATTLE-SHIPS.

On the 17th August, 1888, a special meeting of the Board of Admiralty took place at Devonport (during the annual inspection of the yard) for the purpose of discussing the principal features to be embodied in the designs of first-class battle ships proposed to be laid down in 1889–'90.

The members of the board had before them the particulars of the designs of the most recent battle-ships constructed or in course of construction for the royal navy and for foreign navies, and passed in review the systems of armament and protection embodied in various types.

The questions of speed, coal endurance, freeboard, principal and secondary armament, armor protection, etc., were all separately considered, and a provisional decision arrived at for the guidance of the Director of Naval Construction in preparing alternative outline designs to be subsequently submitted to the board.

After contrasting and comparing the various *dispositions of armament* illustrated in different types of battle-ships, it was unanimously agreed that the following principles should be complied with in disposing the armament of the new battle-ships:

(1) That there should be four heavy guns placed in two protected stations situated at a considerable distance apart, each pair of guns having an arc of training of about 260°, equally divided on each side of the line of keel. All four of these guns to be available on each broadside.

(2) That the greater portion of the auxiliary (or secondary) armament should be placed in a long central battery situated between the two heavy-gun stations, and so disposed that there should be practically no interference with the fire of any one gun by that of any other.

(3) That in view of the development of high explosives, it was desirable to secure the widest possible distribution of the guns in the auxiliary armament, and that it was preferable to mount the auxiliary armament on two decks, one of them being the spar-deck, rather than to carry the guns chiefly between decks.

The best modes of protecting the guns and guns' crews in the auxiliary armament were debated, but a final decision was reserved until the experiments intended to be carried out in the *Resistance* had been completed.

This disposition of the armament was not decided upon without careful comparison of its advantages and disadvantages with those of other systems. For example, the system exemplified in the *Impérieuse* and *Warspite* and in many foreign ships where the protected stations are multiplied and each contains one heavy gun.

The isolation of single heavy guns was seen to have some advantages, but experience in the *Warspite* and *Impérieuse* had shown that with this disposition of the heavy guns there must be a considerable interference with the efficiency and power of independent action of the auxiliary armament; and to protect these four separate positions necessarily required the expenditure of a very much greater weight of armor for a given thickness than was involved in the construction of two stations each containing two guns.

Other plans for carrying the heavy guns in positions where their comparative *concentration* would enable a reduced area of protective armor to suffice also came under review.

Many illustrations of the general idea of concentrated heavy armaments were considered, including "central citadels," with the heavy guns carried in turrets or barbettes and placed either abreast one another or *en echelon*, central batteries with broadside armaments, or citadels placed high above water and isolated from the hull armor.

It was considered that the objections to all these plans were too serious to permit of their adoption, and that these objections might be grouped under two principal heads, viz:

(1) The great risk of the principal armaments being placed *hors de combat* by the explosion of a single heavy shell within or under the armored inclosure.

(2) The enormous difficulties which this disposition of the main armament introduced into the efficient working of a powerful and numerous auxiliary armament.

It was also noted, before recording the decision above mentioned, that in some of the most important foreign navies where one or other of these modes of disposing the armament had been adopted, and the principles either of extreme distribution or of relative concentration had been carried out, the latest designs had contained arrangements similar to those decided upon as best for future battle-ships in the royal navy, which disposition is also to be found represented (in plan) in vessels like the *Trafalgar* and in the *Admiral* class.

This decision of the board respecting the best disposition of the armament necessarily exercised a preponderating influence upon the preparation of all the designs in which it should be embodied. But it left open the question of the extent and character of the protection to be given to the ships by means of vertical and deck armor, as well as the protection of the armament, and the adoption of the turret or barbette system. It was desired to base a decision on these features upon the consideration of alternative designs for ships of about the same size and cost, which should provide for either the barbette or the turret system of mounting the heavy guns and for moderate or high freeboard at the extremities.

After full consideration the board came to the conclusion that each first-class battle-ship should carry four 13½-inch 67-ton B. L. guns as the principal armament, thus corresponding to that carried by the *Trafalgar* and other recent battle-ships.

Further, that the auxiliary armament should include ten 6-inch guns (preferably of the quick-firing* type) and a considerable number of 3-pr. or 6 pr. quick-firing and machine guns.

It was provisionally decided, also, that the length of the armor belt in the region of the water line in the new ships should bear the same ratio to the total length of the ship as in the *Trafalgar.*

On these and other instructions received subsequently from the board as to details a considerable number of outline designs were prepared for both turret and barbette ships, and detailed particulars of relative sizes and costs were placed before the board.

In the interests of the public service it is not desirable that this detailed information should be made public, but the following brief summary and illustrative diagrams will make clear the principal features in the designs from amongst which a selection was eventually made:

For convenience these may be arranged in two groups, viz, the turret ships and the barbette ships.

The *Trafalgar* was taken as the typical turret ship with which to compare the other designs.

The principal particulars of the *Trafalgar as designed* are given in column 1 of the tabular statement herewith, and the general disposition of the armor and armament are illustrated in Plate IV.

It must be stated that, while the particulars given in the table are for the *Trafalgar* as designed, the completed ship will probably be about 10 inches in excess of the designed draught and about 500 tons in excess of her designed displacement; various additions having been made to the armor and armament, etc., during her construction.

Furthermore, in the case of the *Trafalgar* the nominal load displacement, as designed, does not include the board margin of 4 per cent., which now has to be provided in all new designs, and which in her case would involve a further addition of about 10 inches to the draught if she were being redesigned.

In other words, if a simple repeat of the *Trafalgar* were now ordered, it would be necessary to considerably increase the length, and with it to lengthen the belt of armor, in order that the necessary displacement might be provided within the limits of draught accepted in the original design, provision being made at the same time for the board margin of 4 per cent. on the displacement.

---

* Rapid-fire.

In all the alternative designs for turret ships put before the board the mean draught of 27½ feet has been treated as a maximum, the freeboard has been kept the same as in *Trafalgar*, the height of the turret guns above water has been increased about 2 feet, and the more powerful auxiliary armament has been embodied, being accommodated in a longer central battery than exists in the *Trafalgar*.

In all these designs the water-line has been protected by a belt of armor extending for about two-thirds the length of the ship, the depth of the armor below water being 5½ feet, and the height of the belt above water 3 feet.

Two alternative arrangements have been considered for the protection of the turret bases and loading apparatus. In the first the turrets stand at the end of a long armored citadel extending to the full breadth of the ship, and with vertical armor on the sides rising to a height of about 11 feet above water. The upper deck over the citadel is protected by 3-inch steel. In the alternative arrangement the 3-inch steel deck is placed at the height of the top of the belt armor, and each of the turrets is placed in a separate lozenge-shaped redoubt, strongly armored, and inclosing not merely the turret bases, but also the upper portion of the ammunition hoists and the loading appliances.

The broadside of the ship in this case is protected from the top of the belt to a height of about 10 feet above water by vertical armor 5 inches thick extending over practically the same length as the citadel extends in the other plan, and the ends of the space so protected are closed in by armored screen bulkheads extending to the height of the spar-deck.

The first arrangement is sufficiently illustrated by Plate IV for the *Trafalgar*. The second is illustrated on Plate V, which shows the principal features of the disposition of the armor in a turret ship with separate redoubts and thin side armor above the belt.

As a matter of information, the particulars of two designs, one armored on the citadel plan and the other with separate redoubts, are given in columns 2 and 3 of the tabular statement herewith. These two ships, it will be observed, are identical in dimensions, water-line protection, armament, engine power, speed, and coal supply. In the one case, with a continuous citadel, the armor on the turret is 15 inches, and that on the citadel sides 14 and 12 inches; whereas in the ship with separate redoubts the armor on the turrets is 18 inches and that on the redoubts 17 inches. The broadside armor is 5 inches thick above the belt.

It will be seen, therefore, that the adoption of the redoubt system, when it is associated with a long central battery containing the powerful auxiliary armament provisionally decided upon, enables a very appreciable increase to be made in the defense of the turret bases, the turret guns, and of all the loading appliances, as compared with what is possible when the continuous citadel is adopted.

It should be explained that in both cases the defense afforded by the side armor fitted above the belt will be re-enforced by continuous coal-bunkers, which, when filled, will contribute to the defense, and when empty will form cellular compartments in the rear of the armor.

Keeping to the main features illustrated in two designs thus briefly described, investigations were made also to determine what additional cost would be involved in adding to the speed and coal endurance as designed for the *Trafalgar;* and particulars of the approximate dimensions and cost of two turret ships having a natural-draught speed of 17 knots, a coal endurance about 30 per cent. greater than that of the *Trafalgar*, and similar belt protection, were placed before the board for consideration.

It is unnecessary, however, to reproduce these particulars, as it was decided that it would be undesirable to incur the extra expense and increase of size involved in securing these variations from the design of the *Trafalgar*.

Furthermore, an investigation was made as to what could be done on a displacement of about 12,000 tons, inclusive of the board margin of 4 per cent., if the same freeboard, speed, and coal endurance were accepted as designed for the *Trafalgar*, the same proportionate length of armor belt adopted, and the auxiliary armament kept identical with that in all the other designs.

The results are shown in column 4 of the tabular statement, and as there given they correspond to a double-turret ship with each turret placed in a separate redoubt.

For purposes of comparison with the turret-ship designs, a series of designs were also prepared for several barbette ships, in which should be embodied the following features: Greater height of freeboard at the ends; four heavy guns placed high above water in two separate barbettes, and a central battery containing an auxiliary armament identical with that provided for in the turret ships.

These designs differed from the preceding barbette ships of the *Admiral* class in two essential features, which will be sufficiently understood by reference to Plates VI and VII.

It will be seen that the armored barbettes are carried at a considerable height above the armored portion of the hull, the connection for the ammunition hoists and passages being protected by armored tubes.

In these features the *Admiral* class resemble the barbette ships in foreign navies, but in the strength of the protective armor on the tubes and in the general protection of the loading arrangements and gun mountings the English type of barbette is far superior to that to be found in most foreign war ships.

It was decided, however, in view of the great development of high explosives, that in any new designs for barbette ships the proportion of the length at the water-line protected by the belt of armor should be greater than the corresponding proportion in the *Admiral* class; and, further, that the armored barbette towers should be carried down to the top of the belt, in order that there should be no possibility of the bursting of shells containing large explosive charges under the floors of the barbettes upon which the revolving gun-platforms are carried. This feature is illustrated in Plate VII.

The second point of difference, as compared with the *Admiral* class, is to be found in the increased freeboard at the extremities.

It was decided that in the barbette designs the broadside from the top of the belt armor to a height of about 10 feet above water should be protected by armor of moderate thickness, as in the redoubt turret ship illustrated by Plate V.

The series of designs for barbette ships was practically coextensive with that for the turret ships. In order that a definite comparison might be made, each design for a turret ship was associated with a design for a barbette ship of identical external dimensions and draught, the same displacement, the same coal endurance and armament, the same extent and character of armored protection at the water line belt and on the broadside, and the same thickness of protective deck.

In the tabular statement herewith are given the particulars, in columns 6 and 7, of two of these barbette designs, as well as the corresponding particulars for the *Anson* as built.

The two new barbette designs will be seen to correspond respectively in dimensions, displacement, etc., with two turret-ship designs, for which particulars are given in columns 3 and 4.

It was furthermore arranged that in each case the cost of the barbette ships and of the turret ships should be practically identical.

It will be seen that the heavy guns in the barbette ships are carried 6 feet higher above water than in the turret ships, and that the height of freeboard forward and aft in the barbette ships is 18 feet, as against about 11¼ feet in the turret ships.

One point which received the most careful consideration in relation to all the designs, whether for turret or barbette ships, was the protection proper to be given to the guns in the auxiliary armament, in view of the development of high explosives and quick-firing guns of large calibre.

On this matter a provisional decision was reached, and experiments were arranged which are now about to be completed in the *Resistance*.

But pending the completion of these trials and their analysis, it is undesirable to make public any particulars of the methods likely to be adopted.

It will be sufficient to say that a liberal allowance of weight has been made for the protection of the guns in the auxiliary armament and of the guns' crews, as well as for the rapid transport of the ammunition and its protection in all the stages of its passage from the magazines to the guns.

Particulars of outline designs for first-class battle-ships.

	1	2	3	4	5	6	7
	Trafalgar (as designed).	*Citadel*, turret ship.	Redoubt turret ship (design C). (Adopted.)	Redoubt turret ship.	Barbette ship, *Admiral* type (completed).	Barbette ship (design c). (Adopted.)	Barbette ship.
Length … feet	345	380	380	350	330	380	350
Breadth … do	73	75	75	70	68.5	75	70
Draught (mean) … do	27.5	27.5	27.5	27	27–10	27.5	27.5
Displacement (approximate) … tons	12,000	14,000	14,000	12,000	10,550	14,000	12,000
Freeboard, forward and aft … feet	11.25	11.25	11.25	11.25	10.25	18	18
Heavy guns above water … do	15	17	17	17	20	23	23
Horse-power, forced draft …	12,000	13,000	13,000	12,000	11,000	13,000	12,000
Speed, forced draft … knots	16.5	17	17	17	16.75	17	17
Speed, natural draft … do	15	15	15	15	15	15	15
Coal carried … tons	900	900	900	900	900	900	900
Armament							
Main …	4 67-ton B. L.	4 67-ton B L.	4 67-ton B. L.	4 45-ton B. L.	4 67-ton B. L.	4 67-ton B. L.	4 45-ton B. L.
Auxiliary …	8 5-inch B. L. 8 6-prs. 10 3-prs.	10 6-inch R. F. 10 6-prs. 8 3-prs.	10 6-inch R. F. 10 6-prs. 8 3-prs.	10 6-inch R. F. 10 6-prs. 8 3-prs.	6 6-inch B. L. 12 6 prs. 7 3-prs.	10 6-inch R. F. 16 6-prs. 8 3-prs.	10 6-inch R. F. 16 6-prs. 8 3-prs.
Length of belt … feet	230	250	250	230	150	250	230
Armor:							
Belt … inches	20 to 14	18 to 14	18 to 14	14	18	18 to 14	14
Turrets … do	18	15	18	13	…………	…………	…………
Citadel, redoubts, or barbettes … do	18	14	17	13	14	17	13
Side between bases of barbettes or turrets … do	16	12	5	4	Unprotected.	5	4
Armor tube, or base of barbettes … do	…………	…………	…………	…………	12	17	13
Conning tower … do	14	14	14	14	12	14	14
Auxiliary armament …	Unprotected.	Protected.	Protected.	Protected.	Unprotected.	Protected.	Protected.

NOTES OF DISCUSSION ON DESIGNS FOR BATTLE-SHIPS.

On the 16th November, 1888, a meeting took place in the First Lord's Room, which was attended by the undermentioned officers for the purpose of discussing the alternative designs for first-class battle-ships, which has for some time past been under the consideration of the board, and particulars of which for some time had been distributed to the other naval officers present.

Present: The right honorable the Lord George Hamilton, M. P., Admiral Sir Arthur Hood, K. C. B., Vice-Admiral Sir A. H. Hoskins, K. C. B., Rear-Admiral J. O. Hopkins, Controller of the Navy, Rear-Admiral C. F. Hotham, C. B., A. B. Forwood, esq., M. P., Admiral Sir W. Dowell, K. C. B., Admiral Sir R. Vesey Hamilton, K. C. B., Vice-Admiral Sir F. Richards, K. C. B., Vice-Admiral J. K. E. Baird, Captain Lord Walter Kerr, R. N., A. D. C., the Director of Naval Ordnance, and the Director of Naval Construction.

Rear Admiral Sir George Tryon, K. C. B., was unavoidably prevented from attending the meeting, but had placed his views on the subject before the first lord.

At the commencement of the proceedings the First Lord explained that it was the desire of himself and the members of the board to obtain the opinions of the representative naval officers present, who had recently had experience as commanders-in-chief on different stations and in the manœuvres, as regards the principal features that should be embodied in the design of a first-class battle-ship, in order that modern conditions might be most satisfactorily fulfilled.

To facilitate the discussion, reference would be made to the alternative designs for first-class battle-ships, with especial reference to the designs of vessels of about 14,000 tons displacement.

Taking the several features of the designs in order, the opinion of the naval officers was invited on the following points:

1. SPEED.

Were the speeds of 15 knots for continuous steaming (with natural draft under favorable circumstances), and about 17 knots as the maximum speed (with forced draft), regarded as sufficient for first-class battle-ships?

The general opinion was that these speeds were sufficient in view of the considerable increase in size and cost involved in obtaining higher speeds; and that it would be preferred with a given expenditure to have a larger number of vessels possessing these speeds, rather than one or two vessels of higher speed.

2. DISPOSITION OF ARMAMENT.

After some discussion, and after further explanations had been given of the alternative arrangements for disposing armaments in use in other navies, it was unanimously agreed that the general features of the disposition of the heavy guns, and of the auxiliary armament, illustrated in the vessels of the *Admiral* class, as well as in the *Nile* and *Trafalgar*, were on the whole the best possible.

It was recognized that the distribution of the heavy guns in a larger number of armored inclosures (as in the *Impérieuse* class of the Royal Navy, and in the majority of the battle-ships of the French Navy), had its advantages; but that the concurrent disadvantages in relation to the greater weight of armor required for the protection of the guns, and the interference of the fire of the heavy guns with the auxiliary armament, more than compensated for those advantages.

Furthermore, it was agreed that the principle of concentrating the heavy guns amidships, in order to increase the thickness of armor by diminishing its area, was not one which should be adopted, in view of the risks to the simultaneous disablement of the heavy guns incidental to that arrangement, and to the interference of the fire of those guns with the effective fighting of the auxiliary armament.

3. DISTRIBUTION OF ARMOR.

(*a*) Water-line protection: Was it desirable to carry on the belt to the stem and stern, instead of having *unarmored ends?*

It was generally agreed that when the belt was carried over such a large portion of the length of the ship as in the designs under consideration, so that the spaces above the protective deck, before and abaft the belt, were of small capacity and the entry of water to them would produce only small sinkage and very moderate change of trim, then it was preferable to dispose the weight available for water-line protection in the form of thicker armor on the belt not carried to the ends.

The question of fitting thin armor over the bow from the protective deck upwards was also discussed in its relation to the prevention by such thin armor of the riddling of the ends by the fire of light guns, which riddling might possibly admit considerable quantities of water forward and prevent the vessel being driven hard in a seaway.

It was agreed that if such armor were fitted at all it should be carried to a considerable height above the normal water line, which would involve a considerable additional weight; and, in the opinion of nearly all who took part in the discussion, it was preferable, if any weight were disposable for increasing the thickness of the armor, to utilize it in increasing the thickness of the armor on the broadside, from the belt up to the main deck, rather than to dispose of it in the form of protection to the unarmored bow.

(*b*) The alternative dispositions of armor shown on designs of which particulars are given in columns 2 and 3 of tabular statement annexed to the description of the alternative designs, were also considered, with special reference to the relative thicknesses of armor stated to be admissible in those two designs, After full discussion it was agreed—

(*a*) That it was preferable to have two separate strongly protected stations for the four heavy guns, rather than to have a single citadel.

(*b*) That on the whole the 4-inch armor amidships from the belt deck to the main deck, associated as it would be with the internal coal bunker, subdivided into numerous compartments, might be considered satisfactory; but that if armor weight became available it could be profitably utilized in thickening the 4-inch steel above the middle portion of the belt.

This was subsequently made 5 inch.

(*c*) It was also generally agreed that proper protection should be given to the guns and guns' crews of the auxiliary armament.

4. FREEBOARD AND THE MAINTENANCE OF SPEED AT SEA.

It was agreed that for the maintenance of speed and fighting power at sea the high freeboard and high-placed guns in design for barbette ship (column 6 of tabular statement) were preferable to the lower freeboard and less height of guns in design for the turret ship of same displacement (column 3 of statement).

5. BARBETTES VERSUS TURRETS.

The advantages and disadvantages of both systems having been reviewed, it was agreed (in view of the vessels existing in foreign navies or now under construction) that the barbette arrangement in design *c* (col. 6) was to be preferred in a battle-ship intended for general sea-going purposes.

Sir Arthur Hood recommended that of the ships proposed to be laid down in 1889–'90, in the dock-yards, one should be on the turret system.

6. NATURE OF HEAVY ARMAMENT.

There was a considerable weight of opinion that a 12-inch gun of modern design and of about 50 tons in weight might be made, which would possess sufficient power for most purposes; but as no such gun was in existence, and as guns of 75 tons in weight were carried in existing foreign ships, while the 67-ton, 13½-inch gun was thoroughly successful, and all the details of the ammunition and mountings had been settled, it was generally agreed that for the three leading battle-ships 67-ton guns were to be preferred for the heavy armament.

Certain matters of detail in relation to the equipment of the vessel, the masting, signaling, boats, etc., were also discussed.

J. O. HOPKINS,
Rear-Admiral, Controller of Navy.

NOTE.—Designs C and *c* (cols. 3 and 6) were subsequently ordered by the board to be worked out in detail for guidance in building.

It has been found possible to increase the speeds to about 16 knots with natural draft and 17½ knots with forced draft in the completed designs.

3.

ON THE DESIGNS FOR THE NEW BATTLE-SHIPS.

By W. H. White, F. R. S.,

Assistant Controller of the British Navy and Director of Naval Construction.

[Read at the thirtieth session of the Institution of Naval Architects.]

It has been the practice in this institution, from its commencement, to devote no inconsiderable part of the proceedings to discussions relating to war-ship construction generally, and to the royal navy in particular. Including among its members as it does many most eminent naval officers, as well as the leading ship-builders and marine engineers of the world, no better opportunity can be secured for the investigation of the scientific and professional questions incidental to war-ship design. On many previous occasions members of the institution occupying the position which I have now the honor to hold, and gentlemen occupying equally responsible positions in foreign navies, have brought forward descriptions of new types of ships, or problems arising out of their official work, and always with advantage to the public service as well as to the institution.

Recognizing the great interest which is now being taken in the designs of the eight first-class battle-ships which are proposed to be added to the navy, and feeling convinced that no equally suitable opportunity could be obtained for replying to criticisms of the designs which have appeared in the public press, I applied for and obtained permission from the First Lord of the Admiralty to prepare this paper.

Its principal object is to describe the main features of the approved designs for these battle-ships, and to contrast their protection, armament, speed, and coal endurance with the corresponding features in other battle-ships designed during the last twenty years. Incidentally it will be made clear that there are good reasons why these ships surpass in size any previously constructed vessels of the royal navy.

As I proceed with the description it will be my endeavor to deal as fairly and candidly as possible with the adverse criticisms which have been launched against certain features of the designs, and to show that they are not well founded. In doing this I shall treat chiefly of matters of fact, and as to matters of opinion shall describe the reasons which led to the decisions embodied in the designs. On these matters of opinion we shall probably hear much more in the discussion which will ensue.

The "action taken by the board of admiralty with regard to the preparation of designs" for these battle-ships is fully described in Parliamentary Paper C 5635 of 1889,* and a general description of the designs appears in the "Statement of the First Lord of the Admiralty explanatory of the navy estimates, 1889–'90. (C 5648)." I need not reproduce the particulars of the procedure followed; but it may be safely said that no designs prepared at the admiralty or elsewhere have ever received more thorough and careful consideration by competent authorities.

The choice eventually made by the board was made from amongst a considerable number of alternative designs, and in full view of the most recent types constructed or in course of construction for the royal navy and for foreign navies. Before coming to a decision, the First Lord convened a meeting, attended not merely by the members of the board, but by a number of most distinguished and experienced naval officers. At this meeting were discussed *seriatim* the several features that should be embodied in the design of a first-class battle-ship—speed, disposition and nature of armament, distribution of armor, protection of heavy guns, freeboard, etc. On each of these points the opinions of the officers present were ascertained. Subsequently the board issued instructions as to the designs which were to be worked out in detail with a view to building the eight ships contemplated in the programme.

Two designs have been prepared and approved by the board. In both designs are embodied identical qualities, so far as relates to the disposition (in plan) of the armament; the number and calibre of the heavy guns; the nature, disposition, and protection of the auxiliary armament; the distribution and thickness of the hull armor; the propelling machinery, speed, and coal supply; the complement and equipment; magazines and transport of ammunition; and arrangements for hold-stowage. In principal dimensions and displacement the two types are identical. The essential differences are that while one design is for a turret ship with moderate freeboard at the extremities, and with guns about 17 feet above water, the other is for a barbette ship, with the guns carried about 6 feet higher, and with high freeboard at the bow and stern.

It will be convenient to preface a description of the designs by the consideration of the *disposition of the armament*, a matter of the highest importance, which necessarily exercised great influence upon other features of the design, including (as will be shown hereafter) the distribution of the armor.

---

* The previous paper.

ALTERNATIVE DISPOSITIONS OF ARMAMENT.

The board took into consideration all the principal dispositions of armament adopted in recent years for battle-ships, as well as several proposals that have been made—some of which have been patented—but not yet carried out in practice.

* * * * * * *

During the period 1869–78 very little was done in the designs of Her Majesty's ships in the direction of providing for a numerous and effective secondary armament; but this was not true in foreign navies, and particularly in the French navy.

* * * * * * *

Plate VI represents the disposition of armament in the *Admiral* class. Here the secondary armament is greatly developed and mainly carried in a central battery between the two protected stations containing the four heavy guns.

Plate IV illustrates the very similar arrangements (in plan) adopted in the *Nile* and *Trafalgar*. It will be seen that in these vessels the central battery is shorter and the secondary armament less numerous* than in the *Admirals.*

* * * * * * *

DISPOSITION OF ARMAMENT IN NEW DESIGNS.

After careful consideration of these and other alternative arrangements, the board laid down the following principles for the new designs:

(1) That there should be four heavy guns placed in two protected stations, situated at a considerable distance apart, each pair of guns having an arc of training of about 260 degrees, equally divided on each side of the line of keel. All four of these guns to be available on each broadside.

(2) That the greater portion of the auxiliary (or secondary) armament should be placed in a long central battery, situated between the two heavy gun stations, and so disposed that there should be practically no interference with the fire of any one gun by that of any other.

(3) That in view of the development of high explosives, it was desirable to secure the widest possible distribution of the guns in the auxiliary armament; and that it was preferable to mount the auxiliary armament on two decks, one them being the spar-deck, rather than to carry the guns chiefly between decks.

The reason for this decision will be found in the Parliamentary papers above mentioned. It may be well, however, to briefly summarize the most important points of the discussion.

Under modern conditions, with quick-firing guns and high explosives in rapid development, it is essential to provide every battle-ship with a numerous, powerful, and well-placed auxiliary armament in addition to her heavy guns. The disposition of the armament must be such that, while giving great command to the heavy guns, their fire shall not interfere with or be dangerous to the lighter guns and their crews. Provision must be made, in fact, for the safe and simultaneous working of all the guns under the excitement of action, when precautions which may answer fairly well at drill can not be certainly enforced.

---

* Powerful.—Ed.

Reviewing all the dispositions that have been adopted or proposed, it was seen that the disposition illustrated in the *Admiral* and *Trafalgar* classes was superior to all others in the fulfillment of these essential conditions, and it had other advantages.

Experience in the *Impérieuse* had shown that the system of *distributing* the heavy guns in several armored positions involved a considerable interference with the efficiency and power of independent action of the auxiliary armament. Moreover, the multiplication of protected positions for the heavy guns involves a considerable additional weight of armor for a given thickness, as compared with what suffices for the defense of a less number of stations, each containing two guns.

On the other hand, the principle of *concentration* pushed to an extreme has serious disadvantages and drawbacks, although it enables greater thicknesses of armor to be used within any fixed limit of weight, since it reduces the area to be protected. These objections were considered to outweigh the advantages, and are stated in the Parliamentary papers as follows:

(1) The great risk of the principal armaments being placed *hors de combat* by the explosion of a single heavy shell within or under the armored inclosure.

(2) The enormous difficulties which this disposition of the main armament introduces into the efficient working of a powerful and numerous auxiliary armament.

Experience gained with the vessels of the *Admiral* class has as yet been limited, but it has confirmed the good opinion formed at the stage of design as to the merits of the disposition of the armament; and, so far as I am informed, the general feeling amongst gunnery officers in the service is that the system is best adapted for modern requirements. We may anticipate that on this point the discussion will afford the institution an opportunity of hearing the opinions of naval officers.

I will only add a suggestive fact mentioned in the Parliamentary papers:

> In some of the most important foreign navies, where one or other of these modes of disposing the armament had been adopted, and the principles either of extreme distribution or of relative concentration had been carried out, the latest designs had contained arrangements similar to those decided upon as best for future battle-ships in the royal navy, which disposition is also to be found represented (in plan) in vessels like the *Trafalgar* and in the *Admiral* class.

Referring to Plates V and VII, and to the tabular statement, it will be seen that the disposition and character of the armaments in the turret and barbette designs are practically identical. The barbette ship, being of higher freeboard at the extremities, can carry a few more 6-pounder quick-firers; and her heavy guns are, as before stated, 6 feet higher. But in plan the dispositions are the same, and the secondary armament in the central battery identical.

NUMBER AND CALIBRE OF HEAVY GUNS.

It has been decided that each ship shall carry four 13½-inch 67-ton guns as the principal armanent, with hydraulic apparatus for training, elevating, and loading the guns. The grounds for this decision are stated as follows:

> There was a considerable weight of opinion that a 12-inch gun of modern design, and of about 50 tons in weight, might be made, which would possess sufficient power for most purposes; but as no such gun was in existence, and as guns of 75 tons in weight were carried in existing foreign ships, while the 67-ton 13½-inch gun was thoroughly successful, and all the details of the ammunition and mounting had been settled; it was generally agreed, that for the three leading battle-ships, 67-ton guns were to be preferred for the heavy armament.

This decision has since been applied to all the ships.

In the number and power of their heavy guns the new ships will, therefore, stand on the same footing as the *Nile* and *Trafalgar*, or the four vessels of the *Admiral* class—*Rodney*, *Howe*, *Anson*, and *Camperdown.*

The height of the turret guns above water in the *Trafalgar* as designed was 15 feet; in the new turret ship it will be 17 feet. With the thick armor used for the protection of the turrets and turret bases, this apparently small change in the height of the guns above water involves an additional weight exceeding 150 tons.

In the barbette ships the heavy guns will be 23 feet above water.

AUXILIARY ARMAMENTS IN THE NEW SHIPS.

While the heavy gun armament is practically identical with that of preceding ships, the auxiliary armament is of unprecedented weight and power. In the tabular statement the facts are set out, but I must add some remarks, as there has been serious misunderstanding on this matter.

For example, in a letter published in the Times of March 22, Sir Edward Reed, in comparing the new designs with the *Trafalgar*, said: "There is a small increase in the minor armament. * * * The increase of minor armaments is too small to dwell upon in this connection."

I will endeavor to show how mistaken is the view thus publicly expressed.

As designed, the *Nile* and *Trafalgar* were to carry eight 5-inch guns, besides a considerable number of small quick-firing guns and boat guns. The total weight of this auxiliary armament was a little less than 140 tons. A very short central battery sufficed to contain this armament.

During construction, six 4.7-inch 45-pounder quick-firing guns have been substituted for the eight 5-inch guns. This reduction in the number of guns has been accompanied, however, by an increase in the total weight to about 185 tons, the service regulations providing for a very large supply of ammunition for quick-firing guns.

Turning to the new battle-ships, it will be seen that they are each to carry ten 6-inch 100-pounders, besides a considerable number of smaller quick-firers. The 6-inch quick-firing gun is still in the experimental stage; it will be adopted in these ships if successfully worked out, and weight has been taken for it. So far as *weights* are concerned, these ten 6-inch guns, with their mountings and ammunition, represent no less than 20 *guns of the same calibre*, with the allowance of ammunition hitherto carried.

The total weight of the auxiliary armament in the new ships is about 500 tons, or considerably over *three times* the weight originally assigned to the corresponding armament in *Trafalgar*, and *two and two-third times as great* as the weight of auxiliary armament to be actually carried by that ship.

I may fairly claim that such an increase is not properly described as "small" or "too small to dwell upon." On the contrary, to provide for it has proved one of the principal problems in the design. And those familiar with war-ship construction will know well that in stopping short, as I have done, at a comparison of weights of guns, mountings, and ammunition in the two designs, I have greatly understated my case. For example, to accommodate this auxiliary armament a central battery has to be provided about 170 feet in length, whereas in the *Trafalgar* the central battery is not quite 110 feet in length. The more numerous and powerful 6-inch guns, of course, require considerable additional weights to be worked into magazines, armament fittings, gun supports, etc. And with this increase in armament there has necessarily been associated an increase in complement of over 100 men, as compared with the *Trafalgar*, together with the weights for provisions, stores, and accommodation corresponding thereto. Were these extra weights, which are inevitable when the auxiliary armament is accepted, totaled up, the result would constitute a very large addition to the already large excess which the new ships have to carry.

To members of this institution I need hardly add that such an addition to the *load* to be carried *at a given speed, and on a fixed draught of water*, must involve an increase in the size of the ship, very sensibly exceeding the mere increase in load.

* * * * * * *

I would also make the following extract from the Parliamentary papers, although it is not possible for me to give any details at present:

> A liberal allowance of weight has been made (in the design) for the protection of the guns and the guns' crews, as well as for the rapid transport of the ammunition and its protection in all the stages of its passage from the magazines to the guns.

ARMOR-PROTECTION OF NEW TURRET-SHIP DESIGN.

This can not be better described than by the following extract from the first lord's statement to Parliament:

> The armor-protection of the hull proper includes two principal features:
>
> (1) A belt, 8½ feet broad, extending over two-thirds of the length of the vessel, and having a maximum thickness of 18-inch armor. Transverse armored bulk-heads complete the belt, a 3-inch steel deck is fitted above it, and a strong protective under-water deck completes the protection before and abaft the belt.
>
> (2) The broadside above the thick belt is protected to a height of about 9½ feet above water over a considerable portion of the length by 5-inch armor. Screen bulk-heads similarly armored inclose the central battery.
>
> The protection of the heavy guns consists of 18-inch armor on the turrets, and 17-inch on the redoubts protecting the turret-bases, etc.

The diagrams on Plate V will make this description clearer. It will be seen that each turret stands in a separate battery or redoubt, which rests upon the protective deck, and is strongly armored for the defense of the turret bases and loading apparatus. This system has been previously carried out in the *Victoria* and *Sans Pareil*, in each of which there is only one turret.

The belt armor rises 3 feet above water and extends 5½ feet below water. Its longitudinal extent is sufficient to insure that if the spaces before and abaft it and above the under-water protective deck were flooded, very small "sinkage" and very moderate "change of trim" would ensue. The maximum thickness of the belt armor is 18 inches, as against a maximum of 20 inches in the *Trafalgar;* the minimum thickness at the ends of the belt is the same as in *Trafalgar*—14 inches. The proportion of the length protected by the belt is the same in both cases.

Above this thick armor belt and protective deck, the broadside is armored with 5-inch steel for a length of 145 feet and to the height of the upper deck amidships (9½ feet above water). Oblique armored bulk-heads or screens extend across the protective deck and meet the redoubt armor, thus completely inclosing a lightly-armored citadel with its top at the level of the upper deck (9½ feet above water) having the same extreme length as the central battery, viz, 170 feet. Within the 5-inch steel armor on the sides coal-bunkers are built, extending from the belt to the upper deck, and having an athwartship thickness of 10½ feet. When filled with coal these bunkers would greatly re-enforce the defense; when empty the minimum defense is 5 inches of steel, which is proof against all the smaller natures of quick-firing guns, and against many of the most destructive forms of attack from much larger guns.

In the *Trafalgar* (as illustrated by Plate IV) the two "turrets stand at the ends of a long armored citadel extending to the full breadth of the ship, with vertical armor on the sides (varying in thickness from 16 to 18 inches) rising to a height of about 11 feet above water," according to the original design. In the completed ship this height will be about 10 feet. The upper deck over the citadel is plated with 3-inch steel.

The distance between the centres of the two turrets is about 150 feet; and the central battery between the two turrets (as already stated) has an extreme length of less than 110 feet and a length along the broadside of about 65 feet.

In the new turret ship (Plate V) it has been necessary to provide a much longer central battery (about 170 feet in extreme length) to accommodate the more numerous and powerful guns in the auxiliary armament, and the turrets are placed about 200 feet apart. Consequently, if the citadel system embodied in the *Trafalgar* had been repeated, the length of the thickly-armored sides would necessarily have been considerably increased; and a great additional weight and cost of armor, etc., would have been incurred if the same thicknesses had been maintained, or a considerable thinning of the armor, etc., made necessary if the same total weight had been adhered to.

No point in the new designs received more careful consideration than this. In order to elucidate the matter, alternative designs were prepared for ships of the same displacement identical in all respects, except as regards the adoption of the "citadel" or the "separated redoubt" systems. Some of these designs are described in the Parliamentary papers. I will briefly note one instructive comparison.

Two outline designs were prepared: One closely approximating to the turret-ship proposed to be built; the other for a ship of the same dimensions and displacement, but with a continuous citadel. The same total weight was allowed in both designs for the protection above the belt armor—on the sides, round the turret bases, and on the turrets. Except as regards the adoption of (1) a citadel or (2) of redoubt and thin side armor, the ships were absolutely identical.

In the citadel ship, with the fixed total weight for protection, the thicknesses of armor found to be practicable were: On turrets, 15 inches; on citadel in wake of turrets, 14 inches; on sides of citadel (rising to 11 feet above water), 12 inches.

In the other design the practicable thicknesses were: On turrets, 18 inches; on redoubts (protecting turret bases), 17 inches; on broadside (rising to about 10 feet above water), and on "screen bulk-heads" (completing this thin armor across the ship), 4 inches to 5 inches. That is to say, the latter design gave 3 inches greater protection to the stations of the heavy guns, at the cost of reducing the thickness of armor on the sides from 12 inches to 5 inches, and lowering it about 1 foot. In the redoubt arrangement the 3-inch steel deck (as already explained) was situated at the level of the upper edge of the belt (3 feet above water), and in the citadel arrangement, at the top of the citadel armor (about 11 feet above water).

These and other facts having been placed before the naval officers attending the meeting convened by the First Lord, the following decisions were arrived at:

(*a*) That it was preferable to have two separate strongly protected stations for the four heavy guns, rather than to have a single citadel.

(*b*) That on the whole the 4-inch armor amidships, from the belt deck to the main deck, associated as it would be with the internal coal bunkers, subdivided into numerous compartments, might be considered satisfactory; but that if armor weight became available, it could be profitably utilized in thickening the 4-inch steel above the middle portion of the belt.

I would draw particular attention to the first of these conclusions, since it expresses a most important distinction between the two systems of protection.

With separate redoubts, placed far apart, the two stations are isolated, and there is practically no risk of *simultaneous disablement* by the explosion of shells, or perforation of projectiles from the heaviest guns. Each redoubt offers a small target to the fire of an enemy, and its weakest part, the thick steel protective plating on the top, is of so small extent that the chance of its being struck is extremely remote. Serious damage to the unarmored turret bases, therefore, involves the perforation of the thick vertical armor on the redoubts.

With a single citadel, extending the full breadth of a ship, the case is widely different.

Over a comparatively large area of the protective-deck plating in the neighborhood of each turret, perforation of the deck, or its disruption by shell explosions at any point, involves very serious risk of damage to the turret bases and the loading apparatus. In fact, such damage may be effected and the heavy guns put out of action while the thick vertical armor on the citadel is uninjured. Moreover, as the turrets stand at the ends of a single citadel, there is a possibility of their simultaneous disablement by the explosion of heavy shells within the citadel.

This last risk may be minimized (as in the *Nile* and *Trafalgar*) by constructing armored "traverses" within the citadel; but it can not be wholly overcome so long as both turrets stand in one armored inclosure.

It may be thought that the risk of damage to a 3-inch steel deck situated 11 feet above water is remote; but I think the facts are as stated, when actions at sea are taken into account.

For example, if a ship of 70 to 75 feet beam is rolling only to 10 degrees from the vertical, which is by no means a heavy roll, she presents a target having a vertical (projected) height of 13 to 14 feet to an enemy's fire, and even if she is a steady, slow-moving ship, she will do this four or five times in each minute.

Now, at this angle of inclination, assuming the flight of projectiles to be practically horizontal, even the thickest protective steel decks yet fitted in battle-ships are liable to serious damage from the fire of guns of moderate calibre, and this danger is increased by the employment of high explosives. Of course I do not mean to say that this damage is to follow from fire intentionally aimed at the protective deck; but with a great and sustained volume of fire, such as is possible with a powerful auxiliary armament, and especially with quick-firing guns, it is obvious that there is a very real danger of chance shots injuring seriously the wide expanse of the protective deck at the top of a long citadel.

Again, it must be noted that the chances of damage to a deck placed 10 to 11 feet above water, and with large exposed surfaces in the neighborhood of the turrets when a ship is inclined or rolling, are greater far than those of a deck 7 or 8 feet lower, and with 5-inch armor on the sides protecting the deck from the direct impact of shells containing heavy bursters. It is for the naval gunner to estimate these chances of injury; but, unless I am greatly mistaken, their verdict will be that a far greater number of shots are likely to strike at a height of 8 to 10 feet above water than at a height of 4 to 5 feet.

These considerations I submit amply justify the selection of the separate redoubt system, in association with the thin side armor above the belt, and the lowering of the protective deck to the top of the belt in the new designs.

It may be urged that if the redoubt system be adopted it should be associated with side armor and screen bulk-heads of greater thickness than 5-inch steel, and more strongly backed. This is perfectly practicable, but necessarily costly, involving an additional load of armor and a corresponding increase in the size of the ship.

The Board of Admiralty, and the officers called into council, had in their possession, when considering this question, the most recent and complete experimental data obtained by firing against the *Resistance*, with guns of various calibres (including quick-fires), projectiles of all patterns, and explosives of different kinds.

With this information in their possession, the Admiralty pronounce the thin armor above the belt to be "satisfactory," and give effect to that decision in the designs. Sir Edward Reed, in his letters to the Times and elsewhere, challenges this decision, and uses very strong language in its condemnation, but so far as I am aware he can have no experimental data to go upon, and his objections seem to rest on purely hypothetical assumptions of what kind and extent of damage is likely to happen to a ship, lightly armored above the belt, when she comes under the fire of an enemy's guns.

Apart from any expression of personal opinion, I would submit that it is for the naval architect to prepare alternative plans, showing possible dispositions of the protective material within the limits of weight available in a design. Having done this, it is not his province, but that of naval officers, to determine from their knowledge of gunnery what are the nature and extent of the damages likely to be done in action, and to choose that disposition of the armor which they consider has the balance of advantage. This is the course which has been followed by the Admiralty in dealing with the disposition of the armor on the new designs.

* * * * * * *

On the next page I give a tabular statement showing the character of the water-line protection in a number of British and foreign ships, and the vertical distances to which the armor is carried above and below the designed load water-line.

It is perfectly obvious from this table that so far as the belt proper is concerned, the new ships are on practically the same footing as recent ships built in this country and abroad. But I must repeat that they have above the belt a lightly armored side, which most foreign ships have not. They are to be armored, in fact, to 9½ feet above water, as against 2½ to 3 feet in most foreign ships; the total depth of armored side is to be 15 feet, as against 7½ to 8½ feet in some of the largest foreign ships. Relatively to those ships, therefore, the new designs clearly occupy a good position, and that is the true test.

In passing it will be noted that narrow belts have in nearly all cases been associated with dispositions of armaments placing the guns and their armor protection high above water and far apart.

I do not desire to enter into any lengthy explanation of the reasons which have led to this general adoption of narrow armor belts. Probably the chief reason is to be found in the fact that from the outset the depth to which armor has been carried *below water* has been very moderate.

	Armor as designed.			Beam of ship.	
	Depth of belt below load water-line.		Height of thick side-armor above load water-line.		
	Ft.	*In.*		*Ft.*	*In.*
Bellerophon	6	0	5′ 6″	56	0
Hercules	6	0	8′ 6″	59	0
Devastation	5	0	4′ 2″ amid-ships and aft; 6″ forward	62	3
Fury (design canceled)	5	0	4′ 2″ amid-ships; 6″ forward	62	3
Dreadnought	5	6	11′ 0″ amid-ships; 3′ 0″ before and abaft citadel.	63	10
Inflexible	6 (7′ 0″ at fighting draught.)	0	9′ 8″ 8′ 8″ at fighting draught.	75	0
Trafalgar	5	6	11′ 0″ amid-ships; 3′ 0″ before and abaft citadel.	73	0
New Designs	5	6	3′ 0″	75	0
Amiral Duperré	5	6	2′ 6″	67	0
Amiral Baudin French	5	3	3′ 0″	70	0
Magenta class	4	10	2′ 6″	66	0
Sinope class (Russian)	5	0	11′ 0″ amid-ships; 3′ 0″ before and abaft base of battery.	69	0
Italia and Lepanto (Italian)	Armored deck at side is 6 feet below water as designed.			74	0
Duilio and Dandolo (Italian)	6	0	10′ 0″ amid-ships; 2′ 0″ before and abaft base of citadel.	65	0

In recent years this depth has been somewhat diminished, as will be seen from the table, both absolutely and in relation to the beam of ships.

Of course it may be argued that the depth of armor below water ought to have been increased as ships became larger and broader. That is a separate question, and just now we are concerned chiefly with matters of fact and with comparisons of our ships with foreign ships. As a matter of fact, armor protection goes to a moderate depth below water in all cases. Consequently, it is quite possible, and in fact quite common, for the lower edge of the armor to be *emerged*, either by a very moderate inclination of the ship, or by her motion through still water, or by the movement of waves along her sides, or by her rolling in a seaway; as well as by many possible combinations of these circumstances. This emergence of the armor involves the exposure of the unprotected bottom, and chance shots entering below the armor may destroy the ship, and inevitably will cause damage that must be practically irremediable under the circumstances of action, and must result in the entry of large quantities of water into the vessel, even though she may be kept afloat by her water-tight subdivisions.

The unarmored under-water portions of the sides and bottoms of war ships are, moreover, exposed to serious damage in action by submarine torpedoes and by ramming; but it is unnecessary to dwell on the point.

Contrast with these undoubted risks the risks involved in damage to the sides immediately above the armor belt, and also *above the normal water-line.* The consequences are clearly not so serious in many respects. Something may be done towards stopping or limiting the inflow of water when the damage is done above water. There is no head of water to deal with, as when the bottom below the armor is broken through. The projectiles which enter have opposed to them the protective deck at the top of the belt, and must pass through or seriously damage it before any of the vitals (boilers, engines, magazines, etc.) are attacked. And in the new ships (as already explained) projectiles must pass through the light armor before they can reach most portions of that deck; an immense advantage when high explosives are used.

Given, therefore, armor reaching to a moderate depth below water, a narrow belt is not such an unreasonable mode of protection as has been assumed, and the almost universal practice of adopting it is seen to have some justification.

I will only add one remark, which I feel disposed to apologize for, although it expresses a truth often overlooked in these discussions, viz, that the integrity of the unarmored portions of a ship's bottom lying below the armor is as essential to the maintenance of her stability as the integrity of the sides above the armor belt. Yet it is no exaggeration to say that very frequently, when the gravest fears are expressed of what may result from damage to the out-of-water portions of ships, it is virtually assumed that the parts under water, when floating in still water, are not liable to injury in action. Such assumptions are clearly inadmissible.

* * * * * * *

DESCRIPTION OF THE BARBETTE DESIGN.

Although the foregoing descriptions have dealt chiefly with the turret-ship design for a first-class battle-ship, in order that a comparison might be made step by step with the *Nile* and *Trafalgar*, it is proposed to build only one such ship out of the eight ships to be laid down.

This action is described as follows in the Parliamentary papers:

> *Barbettes* v. *Turrets.*—The advantages and disadvantages of both systems having been reviewed, it was agreed (in view of the vessels existing in foreign navies or now under construction) that the barbette arrangement in design (*c*) was to be preferred in a battle-ship intended for general sea-going purposes. Sir Arthur Hood recommended that of the ships proposed to be laid down in 1889–'90, in the dock-yards, one should be on the turret system.

I will now proceed to summarize the chief points of difference between the designs (see Plates V and VII) to some of which allusion has already been made.

In the barbette ships the freeboard at the ends is increased to 18 feet, or 6¾ feet more than the freeboard in the turret ship, and about 7 feet 4 inches more than in the *Trafalgar* as completed.

The heavy guns are carried 23 feet above water, as against 17 feet in the new turret ship, and about 15 feet as designed, or 14 feet as completed, in the *Trafalgar.*

It is unnecessary for me to dwell upon the great advantages that should result from these changes in the power of maintaining speed and fighting guns in a seaway.

In the royal navy a very large proportion of our most recent and powerful ships are of moderate freeboard, carrying their guns only 12 to 14 feet above water; whereas in foreign navies, in recent years, the heavy guns are chiefly carried from 22 to 28 feet above water, and the freeboard is high.

The decision of the admiralty to largely adopt the barbette design is avowedly based on these facts, and arrived at with a full knowledge of the relative advantages and disadvantages of the turret and barbette systems, after considering designs for turret ships with guns placed at equal height above water and with the same freeboard as the barbette ship.

It will be obvious that the increase in height of freeboard and of guns above water can only be secured by means of additional hull weights and re-arrangements of the armor. What has been done is this: The turrets have been abolished, and the weight of armor, etc., is utilized in adding to the height of the redoubts in which the turret bases stand. The barbettes thus formed are strongly armored from the 3-inch protective deck above the belt upwards, and are divided into two stories.

In the upper story stand the turn-tables carrying the heavy guns; in the lower story will be placed the turning engines and other important portions of the equipment.

In most barbette ships hitherto built, whether English or foreign, the barbettes have been shallow armored cylinders, with plated bottoms, standing on light steel structures at a considerable height above the belt deck. Armored tubes have been fitted to protect the ammunition when it is passed up from the magazines into the barbettes.

This system greatly economizes weight of armor, but the development of high explosives makes it possible that shells containing bursting charges of great energy might be exploded immediately under the floors of the barbettes. Consequently it has been decided in the new ships to adopt the alternative system above described, although it involves a very large expenditure of weight and cost on armor.

The hydraulic system of mounting, working, and loading the 67-ton barbette guns to be carried out in the new ships will resemble closely that already successfully adopted in the *Admiral* class.

As regards the disposition of the belt armor, protective deck, and 5-inch armor, as well as the protection of the auxiliary armaments, the barbette ships are identical with the turret design already described.

SPEED.

It was originally contemplated to adhere in the new designs to the speed that had been first accepted for the *Trafalgar*, viz, 15 knots on the measured mile, with natural draft, and 16½ knots with forced draft. In working out the designs, it has been found possible to increase these speeds to about 16 knots natural draft, and 17½ knots with forced draft.

These estimates of speed are, of course, based upon model experiments made in the admiralty establishment at Haslar, by Mr. R. E. Froude, and upon our analysis of the results of speed trials of recent ships. It was with some surprise, therefore, that I found this estimate questioned by Sir E. Reed in the following passage, in his letter published in the Times of March 22:

> There is a slight alleged increase of speed, one-half a knot. This assumed increase of speed is, however, fallacious, because, as a matter of fact, the *Nile* and *Trafalgar*, having 12,000 horse-power to drive 12,000 tons of ship, will obviously have the advantage in speed of ships which have but 13,000 horse-power to drive 14,000 tons of ship.

This kind of criticism is so extremely popular in its form that I am almost disposed to apologize to the institution for explaining why we may reasonably anticipate a higher speed in the new ships, apart from the practical certitude obtained by means of the model experiments and trials of other ships.

The new ships are to be 380 feet in length, as compared with 345 feet for the *Trafalgar*. They will be 14,150 tons displacement, as against

12,000 for the *Trafalgar* as designed, and 12,500 tons for that ship as completed. Our model experiments show that, for speeds from 10 knots up to 16 knots, the resistances of the two forms are, for all practical purposes, equal; the greater length of the new ships compensating for their greater displacement.

But at speeds higher than 16 knots the longer form begins to gain sensibly on the *Trafalgar*, and at 17 knots the *Trafalgar* form would require about 12 per cent. greater power than the new ships. At 17½ knots the *Trafalgar* form, if it could be driven, would require at least 30 per cent. greater power than the heavier but longer ships. Now this speed of 17½ knots is what is estimated as the maximum (forced draft) performance with 13,000 horse-power in the new ships; while with 9,000 horse-power (natural draft) we hope to reach about 16 knots.

The *Trafalgar's* specified powers are 8,000 horse-power natural draft and 12,000 horse-power forced draft; and I am happy to be able to say that on the measured mile these powers ought to give her speeds of about 15½ knots and 16¾ knots, respectively.

Put in another way the facts are these:

The *Trafalgar* form is well adapted for the maximum speed intended in the design, 16½ knots; it is not well adapted for higher speeds, and even if large additional power could be developed, very little extra speed would be gained. On the other hand, the greater length of the new designs render them suitable for speeds up to and beyond 17½ knots, and if additional power were developed the gain in speed would be appreciable.

I must refer to another passage in Sir Edward Reed's letter before passing on. It runs as follows:

> If the increase of size given to them (the new ships), and the increased cost to be bestowed upon them, were to be judiciously applied by competent persons, the results would be ships having a speed of 20 knots, with a coal supply far beyond that which these ships are to possess. Considering how cheaply speed is now obtained, I can not myself deny that I should like to see our great ships able easily to overtake any enemy's fleet.

* * * * * * *

We are considering at present, however, the case of great battle-ships to be built immediately wherein experiments in engineering are clearly undesirable, and where the certain possession of endurance as well as maximum speed is of primary importance. And apart from this fact I entirely challenge the statement that when speeds of 17 to 20 knots are in question for battle-ships, even of the largest size, increase in speed is to be "cheaply obtained." Experience and experiments are contrary to such an assertion, and the onus of proving it to be true lies on the person who makes it.

Figures might be multiplied to show that my contention is correct; but I will only give two illustrations. In the new battle-ships it requires the horse-power to be doubled in order to pass from 14 knots to

17 knots; but a further doubling of the power would not add another 2 knots. This will scarcely be thought a "cheap" increase of speed.

In the mercantile marine, speeds of 20 knots are being attained in steamers of 12,000 to 13,000 tons' load displacement and 26 feet draught, but 500 to 560 feet in length, and having a ratio of beam to draught and length which is altogether inadmissible for a war-ship carrying heavy weights of armor and armament high above water. But even under these conditions speed is not "cheaply" increased from high speeds such as 17 knots to the still higher speed of 20 knots. To take an actual case within my knowledge, the ratio of the power at 20 knots to that at 17 knots was found to be 2 to 1.

In illustrating the truism that great expenditure of power is inevitable when such a speed as 20 knots is obtained, I do not assert that battle-ships may not be produced having that speed. What I challenge is the statement of Sir Edward Reed that in ships of the size and cost of the new battle-ships "competent persons" could produce ships as heavily armed, more heavily armored, "having a speed of 20 knots, with a coal supply far beyond that which the ships possess." That statement could not have been made if he had given even the most moderate amount of consideration to the enormous power and weight of machinery necessarily required to obtain 20 knots with any possible form of ship; to the serious difficulties involved in providing space for the accommodation of the propelling machinery, boilers, and coal, as well as magazines, store-rooms, etc., under protection in the hold; and to the fact that the maximum draught of water being necessarily a fixed quantity, changes of form, in length especially, and increase in weights of hull and armor, would be unavoidable. All these points are matters of fact, not of opinion. They lie on the very surface of the problem, and they obviously require to be dealt with in a careful scientific manner, not in an airy general style, taking for its basis the idea that speed is now "cheaply obtained."

Before leaving this question of speed, it may be well to point out the fact that these new battle-ships will possess speeds exceeding those of nearly all battle-ships built or building. They will form a squadron of identical character and qualities, capable of proceeding and manœuvring together. Taken as a group, they will certainly be "able easily to overtake any enemy's fleet." And what is equally important, they will under the new programme be associated with a number of very swift cruisers and torpedo-gunboats, thus constituting a force complete in all respects, and of unrivaled power as well as speed.

COAL SUPPLY AND ENDURANCE.

It was decided, after full consideration, that the new ships should ordinarily carry 900 tons of coal, as in the *Trafalgar;* and be capable of covering the same distance, viz, about 7,000 knots at 10 knots.

Like the *Trafalgar*, the new ships will have a bunker capacity sufficient to carry a much larger quantity of coal if desired.

But whereas any increase above 900 tons in the coal put on board the *Trafalgar* necessitates an increased draught and some loss of speed, in the new designs provision is made (in the form of the so-called "board margin") for an unappropriated weight exceeding 500 tons to be carried at the designed load draught and at the full speed.

Strictly speaking, therefore, the case stand thus:

Trafalgar—coal at load draught, 900 tons.

New designs—coal at load draught and unappropriated weight, about 1,400 tons.

If the unappropriated weight should be assigned to coal, it would give the new designs a coal endurance of nearly 8,000 knots at 10 knots.

Apart from any such increase in coal, however, the 900 tons proposed is a very large supply in relation to expenditure; larger, in fact, than that of nearly all first-class battle-ships. Take for example the *Thunderer* and *Devastation* as completed. They can cover about 4,700 knots at 10 knots. Their full speed for continuous steaming in smooth water is estimated at 12½ knots, and they can cover about 2,700 knots. At that speed with 900 tons of coal the new ships could cover about 3,500 knots. At the highest speed contemplated for smooth water, continuous steaming—about 16 knots—the new ships could cover about 1,900 knots. The forced draft speed is never intended to be maintained for more than four to five hours continuously; so that an estimate of coal endurance under these conditions is worthless for any practical purpose.

There is one class of ships in the royal navy (the *Admirals*) which has an unrivaled coal endurance, and one ship in that class, the *Collingwood*, which surpasses the others. This vessel (the *Collingwood*) is selected by Sir Edward Reed as a standard of comparison on which to base a hostile criticism in dealing with the coal capacity of the new ships. Nor is this all, as the following passage will show. He says:

> When the *Collingwood* was designed, she was provided with engines of 7,000 horse-power, and a coal supply of 950 tons. The proposed new ships are to have 13,000 horse-power, and in the same proportion should carry 1,760 tons of coal; but incredible as it may seem, 900 tons of coal is all that is to be allowed them.

It will be sufficient to indicate in the briefest fashion the misleading character of the comparison here made.

(1) The 7,000 *horse-power* mentioned for the *Collingwood* was with *natural draft;* the 13,000 *horse-power* for the new ships is with *forced draft*, their natural draft power being 9,000 horse-power.

(2) The new ships will have triple expansion engines, which may be assumed to be at least 15 per cent. more economical in coal consumption than the compound engines fitted in the *Collingwood.*

(3) The *Collingwood* can steam about 7,000 knots at 10 knots if she starts with 900 tons of coal, her full authorized quantity. The new ships with the same weight of coal will steam 5,000 knots at 10 knots; to cover 7,000 knots they would have to start with about 1,250 tons of coal, or 350 tons more than the ordinary supply of 900 tons. This 350

tons is (as explained above) less by more than 150 tons than the unappropriated board margin which has to be carried at the load draught and full speed in the new ships.

The coal endurance of Her Majesty's ships has to be regulated by other considerations than those of mere comparison with the corresponding feature in foreign ships. To this point I referred at length in the discussion on Sir N. Barnaby's paper on "Fuel Supply," published in the Transactions for 1887. But it may be interesting to state that no foreign war ships, except, perhaps, the *Italia* and *Lepanto*, have coal endurances approaching those of the new designs. And, further, it must be remarked that published statements of coal endurance for foreign ships are frequently based upon mere bunker capacity, and not upon the coal carried at the reputed load-draughts and full speeds.

REMARKS ON THE SIZE OF NEW BATTLE-SHIPS.

In conclusion, I desire to make a few remarks on the criticisms that have appeared with reference to the very large size and displacement of the new battle-ships.

These criticisms may be arranged in two groups:

First. What may be termed the "too many eggs in one basket" class of objection.

Secondly. Those which allege that the ships have been made unnecessarily large in relation to the qualities of speed, coal endurance, armament, and protection they are intended to combine.

The first class are criticisms of the policy represented in the designs, and these I shall leave unanswered, since the Board of Admiralty are responsible for that policy, and I am their technical adviser. But it will be noted that the procedure followed in deciding on the designs involved a selection from amongst a number of alternatives representing ships of various classes, sizes, and costs.

Independently of actual experience in a great naval war, and the experimental demonstration of the relative advantages and disadvantages of a group of smaller ships, as against a less numerous squadron of ships individually more powerful—the aggregate outlay in each case being the same—the choice between the two policies of construction must be largely a matter of opinion. But I presume it will be admitted that the Admiralty and its naval advisers constitute as competent a body as can be found to deal with such matters.

Moreover, it must be noted that in the existing fleet we already have large numbers of battle-ships of less size and cost than the projected vessels; and that the new programme associates with the eight first-class battle-ships two second-class battle-ships of moderate size and a very large number of swift cruisers. So that, taking the fleet as a whole, all views may be considered to be represented.

The second class of criticism is one that peculiarly concerns myself as the responsible designer of the ships; for it really amounts to a charge of professional incompetency. If these ships have been made larger and more costly than was necessary to secure the combination of qualities decided on by the Board of Admiralty, then I primarily, and my colleagues and assistants in the constructive and engineering department of the Admiralty, are clearly to blame.

Sir Edward Reed has made this charge of "incompetency" in unmistakable language in the passage above quoted when dealing with speed.

In dealing with this serious allegation, I desire, however, to sink all personal feeling, and to disregard the attack made on the "competency" of the Admiralty professional officers. My intention is to put a plain statement of facts before the institution, and to allow the facts to speak for themselves. Fortunately my task is easier because Sir Edward Reed has himself requested that the "comparison which he has set up between the *Nile* and *Trafalgar* and the proposed ships" may be tested; and this I will now proceed to do. To make the comparison as precise as possible, I will take the new turret ship design, and, to make it complete in this place, I will repeat some figures already given.

On the tabular statement for the various classes of battle-ships on page 93, the principal particulars for the *Trafalgar* (as *designed*) and for the new ships are compared. Originally the *Trafalgar* was intended to have a load displacement of 12,000 tons, and a mean load draught of 27½ feet, trimming 1 foot by the stern, with 900 tons of coal on board. It is explained, however, in the Parliamentary papers, that owing to various additions made during construction and to other causes, the completed *Trafalgar* will be 500 tons heavier, and draw about 10 inches more than designed. For purposes of comparison, therefore, she must be taken as a vessel of 12,500 tons, having a mean draught of nearly 28½ feet, and an extreme draught aft of 29 feet, with 900 tons of coal on board. When she fills up her bunkers to 1,200 tons she will draw about 6 inches more.

Here then we have the true starting point in the comparison with the new ships: a vessel of 12,500 tons drawing 28½ feet mean and 29 feet extreme.

With these facts before them, the admiralty decided that in the new designs the original mean draught intended for the *Trafalgar* (viz, 27½ feet) should not be exceeded; and this decision is set out in the Parliamentary papers.

Before this institution it is scarcely necessary for me to dwell upon the great influence which this decision to keep to a draught shallower by 1 foot than the actual draught of the *Trafalgar* must have had on the new designs. But Sir Edward Reed, although himself a naval architect, ignores the detailed statement of facts in the Parliamentary papers, and makes no allusion to the consequences.

I will very briefly correct his omission, and state what the change in size would be if the *Trafalgar* were re-designed to float at the 27½ feet mean draught, carrying the same armament, the same equipment, the same armor protection, and to steam at the same speed as the actual *Trafalgar.* To fulfill these conditions would involve an extra length of about 20 feet, and would require a displacement of about 13,000 tons.

Keeping these figures in mind let us turn to the new ships, which are to be 380 feet long, of 14,150 tons displacement, and 27½ feet mean draught.

They are consequently of 1,650 tons greater displacement than the *Trafalgar* as completed, but of 1 foot less draught. They are of about 1,100 to 1,200 tons greater displacement than the re-designed *Trafalgar* floating at the same draught would be.

Now let us see how this difference in displacement (1,100 to 1,200 tons) is made up; and here the ground has been cleared by some of the statements made in the preceding pages.

The following are (in round figures) the excesses *in loads to be carried in the new ships*, quite independent of increase and size:

	Tons.
Auxiliary armament	300
Increased complement, etc	60
Board margin of weight (equivalent to enlarged coal supply)	520
Weight of armor, etc., to lift turret guns 2 feet higher above water than in *Trafalgar*	150
Total increase in load	1,030

To carry this heavier load on the same draught (27½ feet) as the redesigned *Trafalgar* necessarily requires a longer and larger ship, and therefore a heavier hull. Furthermore, in the new ships, as explained above, machinery of greater power than that in the *Trafalgar* is to be provided, not for the purpose of driving the larger ships as fast as the *Trafalgar*, but to obtain an absolutely higher speed, the difference in speed being at least half a knot, and possibly more, in favor of the new ships.

The foregoing statement of facts will probably be found sufficient by members of the institution to explain the increase in size of the new ships, and to illustrate the statement, which I will now add. They have not been made any longer or larger than is absolutely necessary—under existing conditions of naval architecture and marine engineering—to fulfill the conditions laid down by the board.

My friend and colleague, Mr. Sennett, and I are perfectly acquainted with the savings in weight or equivalent increase in power and speed which would be possible if we had adopted certain new types of boilers or novel arrangements of machinery which have undergone limited trials with considerable success.

We are, moreover, most favorably disposed towards the gradual developments of all systems which promise such beneficial results. But we do not consider it wise or right to make such experimental trials on ships of the magnitude and importance of these new battle-ships. And after the fullest consideration our advice to the board has been to adhere to arrangements with which we have experience, and of which the success is assured.

Before sitting down I will add two or three statements which appear to be of some importance when dealing with the relatively large size of the new ships.

First: They have been shown to be made large by the great *loads* of armament equipment and board margin they carry on a moderate draught at high speed.

Omitting the board margin (or allowance for contingent additions during construction) the ships are of 13,600 tons displacement, and about 26 feet 8 inches mean load draught. These are the figures strictly comparable with the other ships: using them the following table is instructive.

	Length.		Mean draught.		Displacement.	Maximum speed.
	Ft.	*In.*	*Ft.*	*In.*	*Tons.*	*Knots per hour.*
New ships (excluding board margin)	380	0	26	8	13,600	17.5
Trafalgar (as designed)	345	0	27	6	12,000	16.5
Inflexible	320	0	25	3	11,880	13.8
Dreadnought	320	0	26	9	10,820	14.2
Minotaur	400	0	26	9	10,690	14.4
Warrior	380	0	26	9	9,210	14.1
Italia	400	6	*31	3	13,900	18
Lepanto	400	6	*30	9	13,550	18
Sicilia	400	0	*28	6	13,253	18
Amiral Baudin	321	6	*26	2	11,380	15

* Extreme draught.

Second. The new ships, although of a displacement surpassing all previous battle-ships,* are certain to be much more manageable than many of their predecessors with equal or greater length and not possessing twin screws.

Lastly, it will be seen that since the increase in size is chiefly due to increase in load, the assumptions that have been made by Sir Edward Reed and others as to relative increase in cost are not well founded. I am not at liberty to make any statement respecting the admiralty estimate of cost for these ships, for reasons which will be obvious. But this I may say, that while the total weight of protective material in the new ships is greater than the corresponding total in the *Trafalgar* by something like 150 tons, the adoption of the 5-inch armor in association with redoubts, instead of a central citadel thickly armored thoughout, has the result of largely reducing the cost of the armor. This was not the reason, however, for the adoption of the system, as has already been explained. At the next meetings of the institution this question of cost may be debated on the basis of ascertained figures, and I therefore say no more.

---

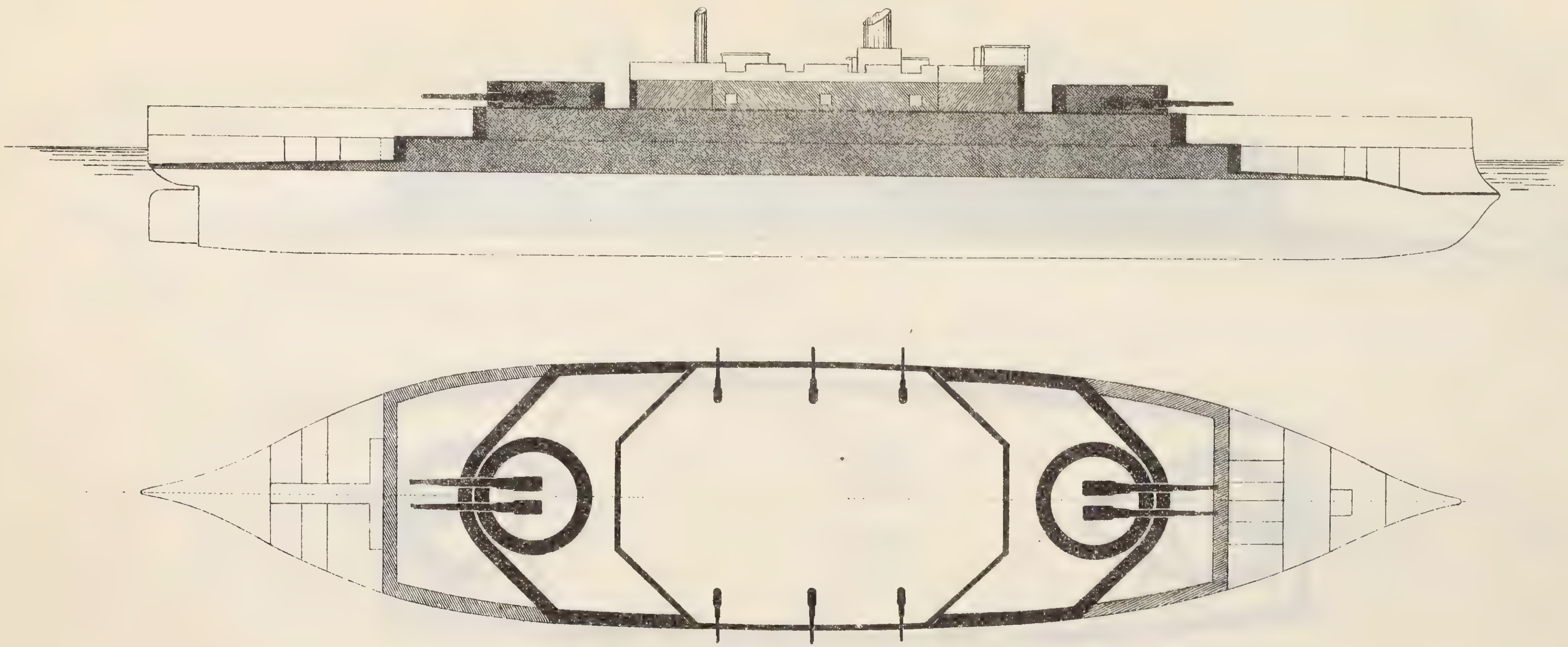
*The present displacement of the *Italia* is 15,360 and of the *Lepanto* 14,860 tons. [Ed.]

The paper has extended to an unusual length, yet I venture to believe that this has been warranted by the importance and range of the subjects treated. It has unavoidably assumed a controversial character in certain parts; but I am not responsible for the circumstances, and I trust that nothing has been said by me which goes beyond fair reply or criticism. I have, in fact, been put upon my defense as a naval architect who holds a position of some public importance, and who should clearly cease to occupy that position if the allegations of incompetency that have been made so freely and publicly could be sustained. But beyond any personal interest in the matter, I appear here as the representative and head of the constructive department of the admiralty—the "Whitehall Office," which is said to be no longer capable of producing "the best possible ships." Apart from the fact that I am the head of that staff, and apart from any question of my personal competence, I desire to state that there never has been a time during my experience of the Admiralty Office—an experience extending over twenty-two years—when the members of that staff included so many thoroughly educated, capable, and qualified naval architects and marine engineers as are now serving there. The great system of technical education, established by the admiralty twenty-five years ago, largely in consequence of the recommendations of this institution, has borne good fruit, and the public service is reaping the benefit, not merely at the admiralty, but in the dock-yards, while outside the service men similarly trained have risen to the highest professional eminence.

If with such a staff, with all our recorded data and experience, with our grand experimental establishment at Haslar, so ably conducted by my friend, Mr. Froude, and with all the valuable assistance and suggestions coming to us from the naval service and our professional colleagues in the dock-yards, as well as the constant benefits we derive from a full knowledge of the work done by private ship-builders and foreign competitors, we do not, in the "Whitehall Office," succeed in producing "the best possible ships" consistent with the instructions of the Board of Admiralty, then there can be no excuse. But I contend that the allegations made against the professional officers of the admiralty have been loosely made, and are proved to be unfounded, as regards the designs of the new battle-ships, by the facts which have been adduced.

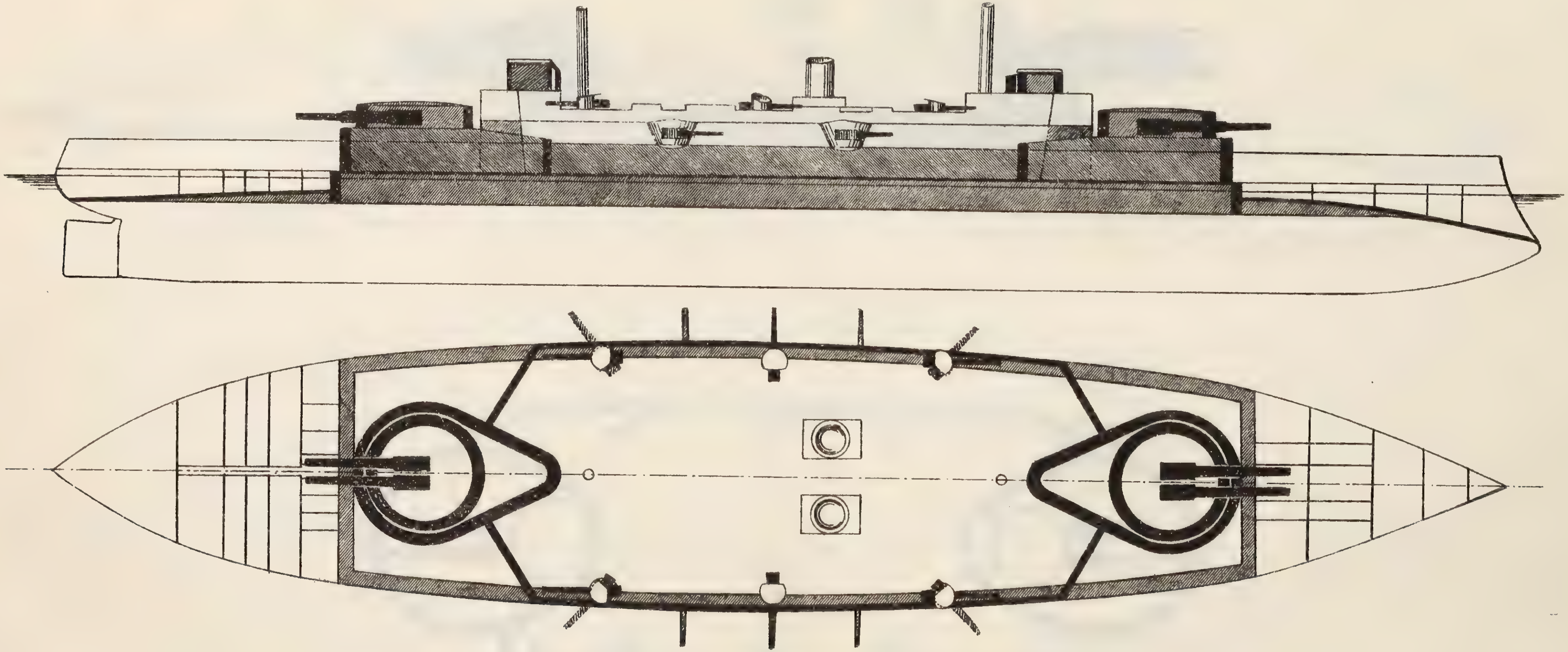
A much more important question than that of our professional competency arises from the discussion; and public interest must chiefly centre in it, since it seriously affects the national defense. Assuming that we have done the best that could be done under instructions received from the Board of Admiralty, the country desires to know whether the ships proposed to be built are "the best possible ships" which can be added to the navy under existing conditions of naval warfare.

PLATE IV.



"NILE" AND "TRAFALGAR"

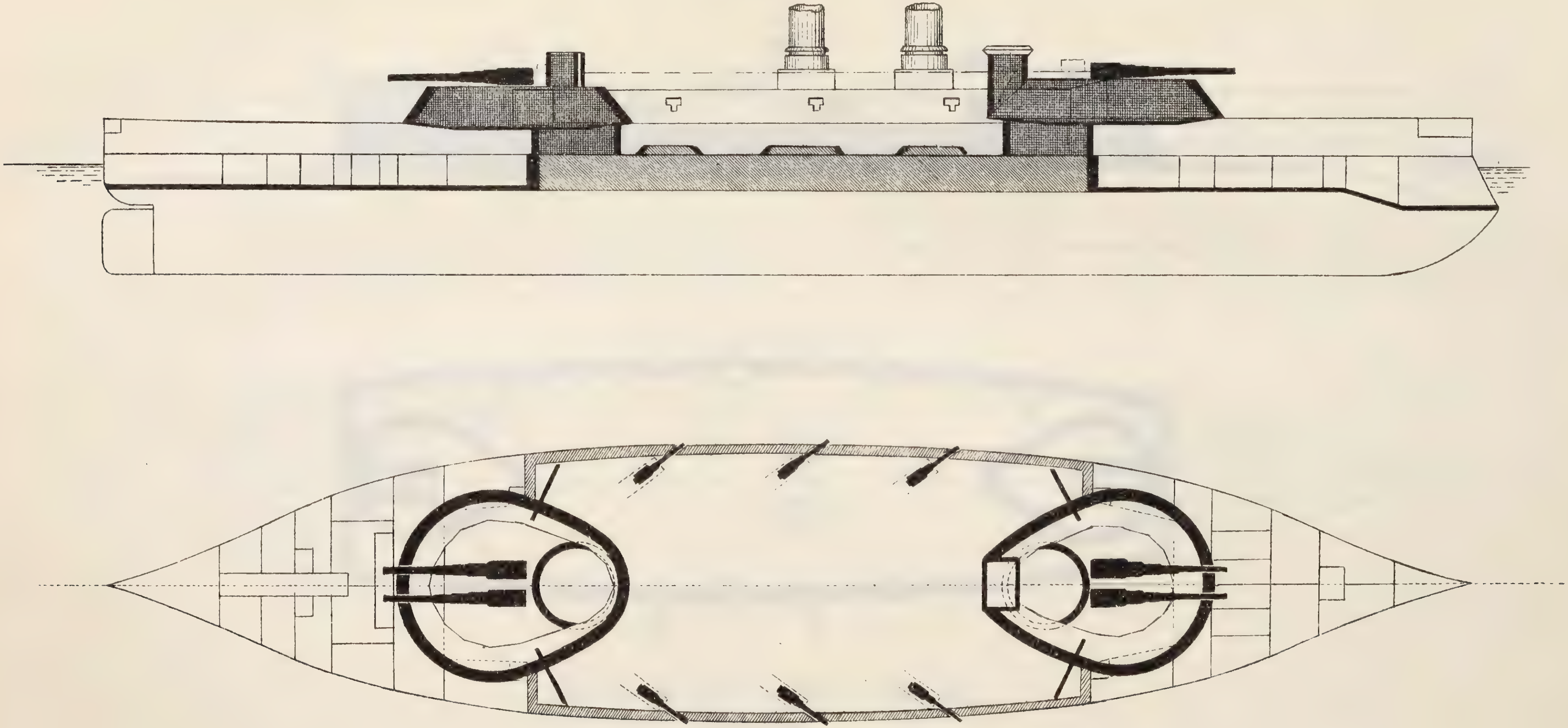
PLATE V.



NEW TURRET SHIP

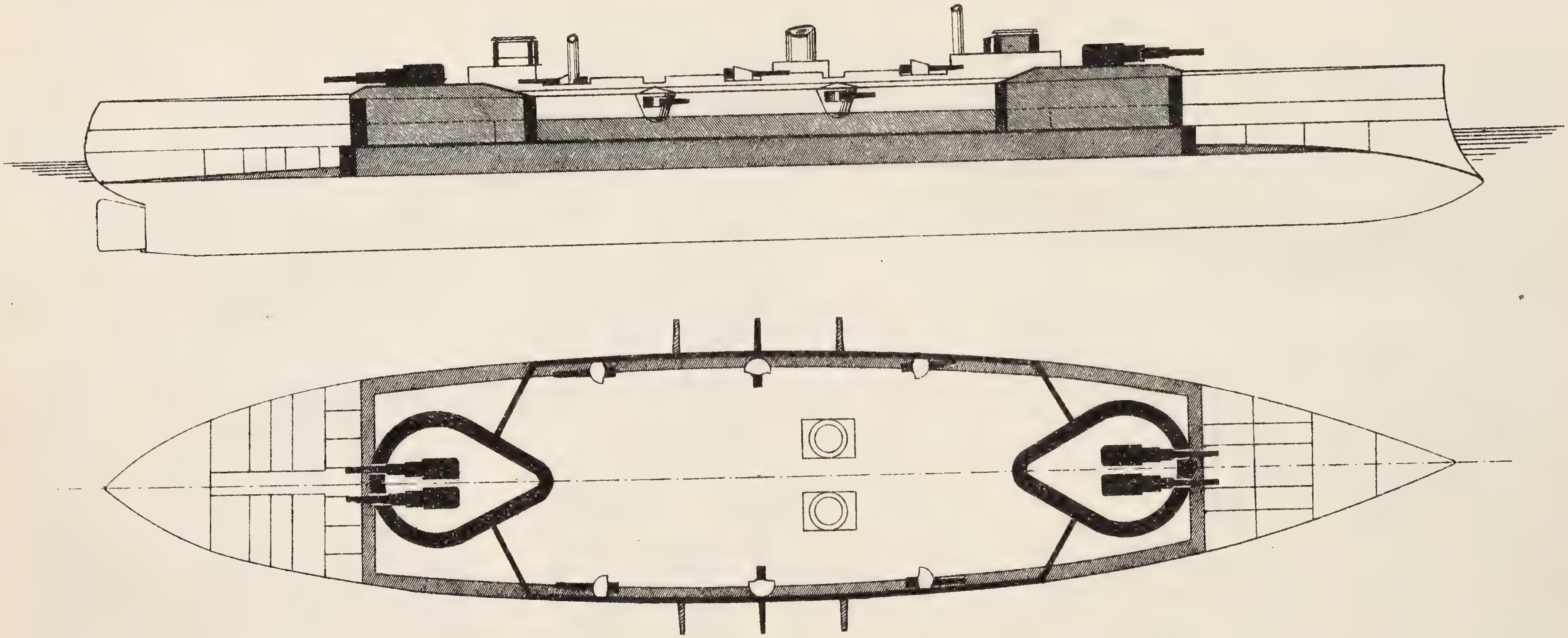
ENGLISH.

PLATE VI.



"COLLINGWOOD"
)

PLATE VII.



"NEW BARBETTE SHIP",
ENGLISH.

On this question I shall not be expected to give an opinion. It involves an inquiry into the competency of the Board of Admiralty and our system of naval administration. But at the risk of repeating statements already made, I must say that there never have been designs more deliberately and carefully considered. The selection was made from amongst a large number of alternative designs, after a careful review of what is being done abroad, and with reference to various proposals not yet embodied in actual ships. Fortunately, it could be based upon a great mass of new experimental data, obtained by actual trials against the *Resistance* and elsewhere, and giving the latest and best information in relation to guns, projectiles, explosives, and armor. Moreover, the Board of Admiralty has availed itself of the advice and assistance of a number of distinguished officers before coming to a decision.

A complete account of the action taken, and the reasons for the various conclusions reached, has been placed before the public. Obviously there is room for differences of opinion, since actual experience in naval warfare under modern conditions is almost entirely wanting. The matter, therefore, resolves itself into one of relative authority and experimental information. Under these circumstances, the naval service and the country will probably prefer to accept the conclusions of a responsible and well-informed body like the Board of Admiralty, rather than those of any individual.

4.

EXTRACTS FROM A PAPER ON "THE PROTECTION OF BUOYANCY AND STABILITY IN SHIPS."

By Sir NATHANIEL BARNABY, K. C. B.

[Read at the thirtieth session of the Institution of Naval Architects, April, 1889.]

I have recently, in fulfillment of a long-standing engagement, prepared for another institution a paper on "Armor for Ships, its Uses and its Nature."

I did not discuss in that paper its uses for protecting buoyancy and stability. Armor was not introduced for the purpose of protecting buoyancy and stability; it was introduced to limit the destructive effect of shell on the batteries.

It answered its purpose so effectively for the moment that artillerists gave up attempts to develop the shell, and directed all their efforts to obtain perforation of the armor by projectiles having no bursting charges. So armor was gradually reduced in area and made thicker and stronger in such parts as were still supposed to need it.

Thirty years after the introduction into the French navy of armor clothing against shells, that navy is found with no armor clothing at all over the batteries of its largest ships. It has been nearly all concentrated upon a narrow belt at the water line.

Artillerists have taken advantage of this condition of nudity and have devised projectiles far more powerful than those against which armor was first employed, and they are once more making existence in the batteries for guns and men impossible.

Plate IX shows, not an actual target, but a representation of what happens when 70 to 80 pounds of a high explosive is detonated between decks.

The French have been so impressed by their experiments with high explosive shells that they have reverted to side armor to prevent the admission of such shells between decks under the guns and gunners.

* * * * * * *

It will be within your recollection that a committee on designs sat in 1871, and included among its members six eminent naval officers, among them the present first sea lord of the admiralty.

This committee directed attention to the desirability of getting reserve of buoyancy by other means than armor plating.

They thought that "the ship might consist of a plated central citadel, surrounded and supported by an unarmored raft, constructed on a cellular system, or containing some buoyant substance, such as cork, which, without offering any material resistance to the passage of projectiles, would not be deprived of its buoyance by penetration."

The late council of construction directed its attention to this for years, and devised india-rubber bags, thin metallic boxes, and various other arrangements for securing this object. But we could never satisfy ourselves. The risk of the collapse of a considerable number of these empty vessels by one shock seemed to us to be very serious.

While, therefore, we proceeded, as far as we could, with a raft body for the ends of the ships, we employed solid substances in those ends for excluding water there. We used cork inclosed in small water-tight chambers; the ship's stores; and spare fuel.

We used these defenses against the invasion of water as supplementary to the armored middle of the water zone; and we made that armored middle only so long as was required to inclose the machinery spaces and the communication between the magazines and the armored batteries.

It is that system which has been so severely criticised. In my judgment it is the right system; and what we have seen to be the cost of an extension of the armor, appears to me to strengthen the position of the designers of the *Admiral* class.

But when we came to consider a design for a sea-going fighting vessel of minimum size and cost, it was obvious that belt armor could not be admitted at all. There were several devices which had been adopted for small war-ships. There was the Armstrong plan, with wings of cork upon a submerged deck. There was the French plan of cellulose dams. These dams act by the expansion of the compressed cellulose (cocoanut fibre) when exposed to the water, as it seeks to pass through a shot-hole in the dam. But this cellulose washes out easily if the hole is large, and it is not to be trusted. I considered that what we needed was a light, non-absorbent solid. I put the problem to the staff of the Naval Construction and Armament Company, but they could make nothing of it. I found that the Woodite Company were making a porous india rubber which would answer admirably for a solid packing. There was nothing against it except that it cost £450 per ton.

I then submitted some of this Woodite material to an eminent chemist, and asked him whether a material could be manufactured possessing the qualities of lightness (not exceeding in weight 22½ pounds to the cubic foot) and non-absorbency of water, at a price for large quantities of £50 per ton. My chemical friend could not help in the matter, but he recommended an appeal, by the way of advertisement, to the chemical profession. Captain Wood then undertook to produce such a material as we were seeking.

He has succeeded so well that he produces the material at so low a weight as 10 pounds to the cubic foot, and with so low an absorbent power that it excludes 96 per cent. of water for twenty-four hours from a packed compartment. It is slowly inflammable, and it is inelastic. It would be better if it were uninflammable and somewhat elastic. But I consider that the material, in its present early stage of manufacture, may be used confidently in the way proposed.

The submerged deck is covered by numerous partitions of thin steel, about one-sixteenth of an inch thick, and these partitions are left uncalked. The partitions rise to some height above water agreed upon, and the compartments are filled in solidly. Upon the upper edges of these thin steel partitions rests a thin steel plating, not calked, and not fitted in a water-tight manner. Water may pass down into interstices left in the packed spaces without any disadvantage that I can see.

The present price of the packing material, or "wood armor," is £45 per ton. Taking its average weight at 13 pounds to the cubic foot, we should get 157 cubic feet of space occupied solidly for £45 worth of material.

The amount used in the Barrow design is between 4 and 5 per cent. of the displacement. It is 18 inches deep in the shallowest place, and 6 feet deep at the sides, where the stability wings are formed. These wings are inclosed in thin steel cases, and extend two-thirds of the length of the ship. The cost of the packing is, in this case, at the price named, £6,000 for the ship.*

The material is doubtless susceptible of improvement. I put it before you as being already suitable for our purposes.

* * * * * * *

The material has the advantage, which side armor has not, that it is applicable to all fighting ships, large and small.

A solid raft, formed upon and above a deck covering the machinery and magazines, and occupying the water zone, is what is wanted in every fighting ship.

I hope that this method of protection may come into use, because it will enable us to give once more reasonable security against foundering, under artillery fire, to all fighting ships. It will allow us to devote some armor to protect the batteries against the attack of the high explosive shell and the quick-firing gun. The present defenselessness of the batteries is no longer tolerable. It will give us both these advantages, consistently with a large increase in the number of ships, and in the power of putting fighting men afloat.

---

* For the Barrow battery-ship, see p. 86.

PLATE VIII.

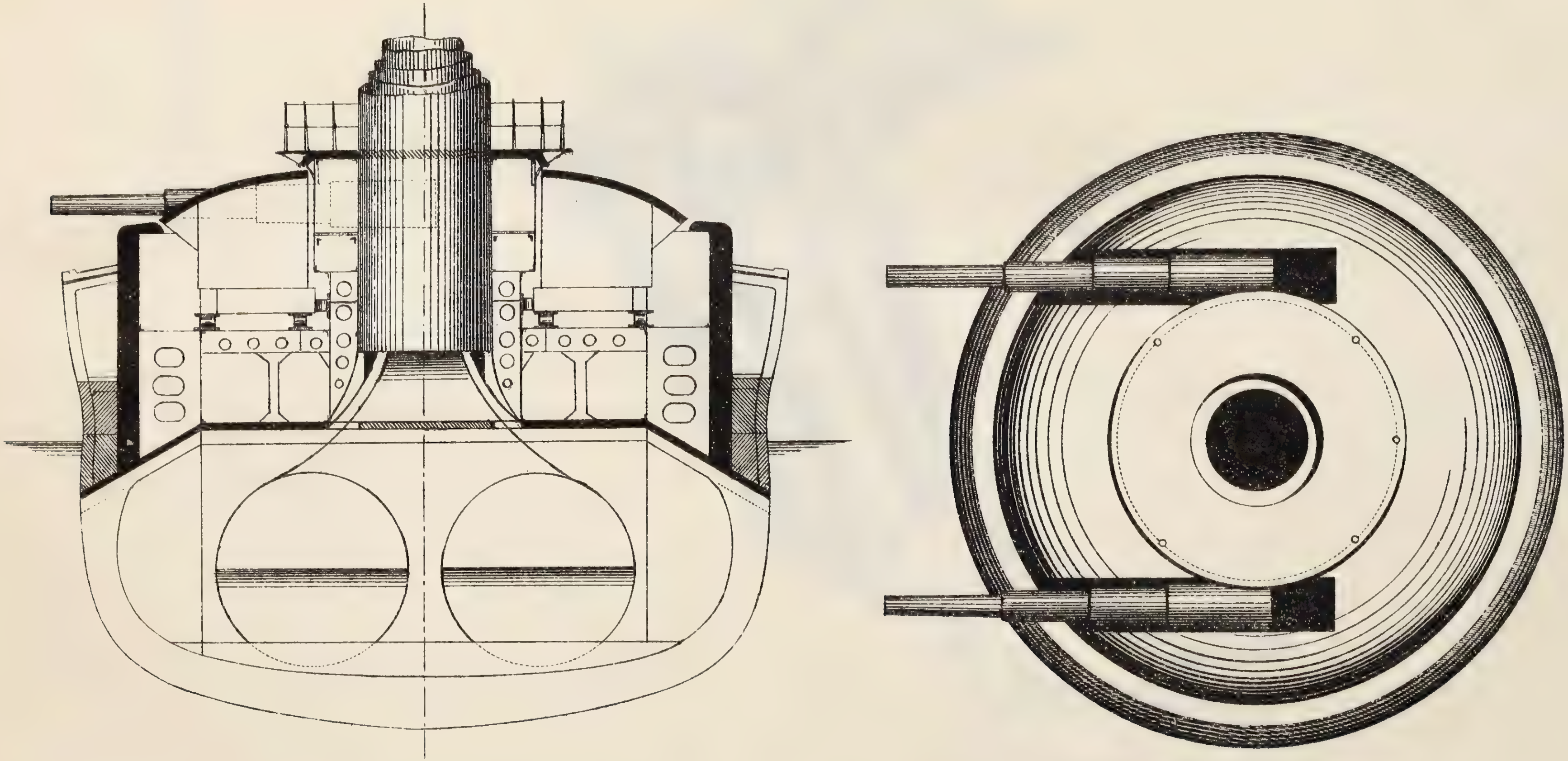
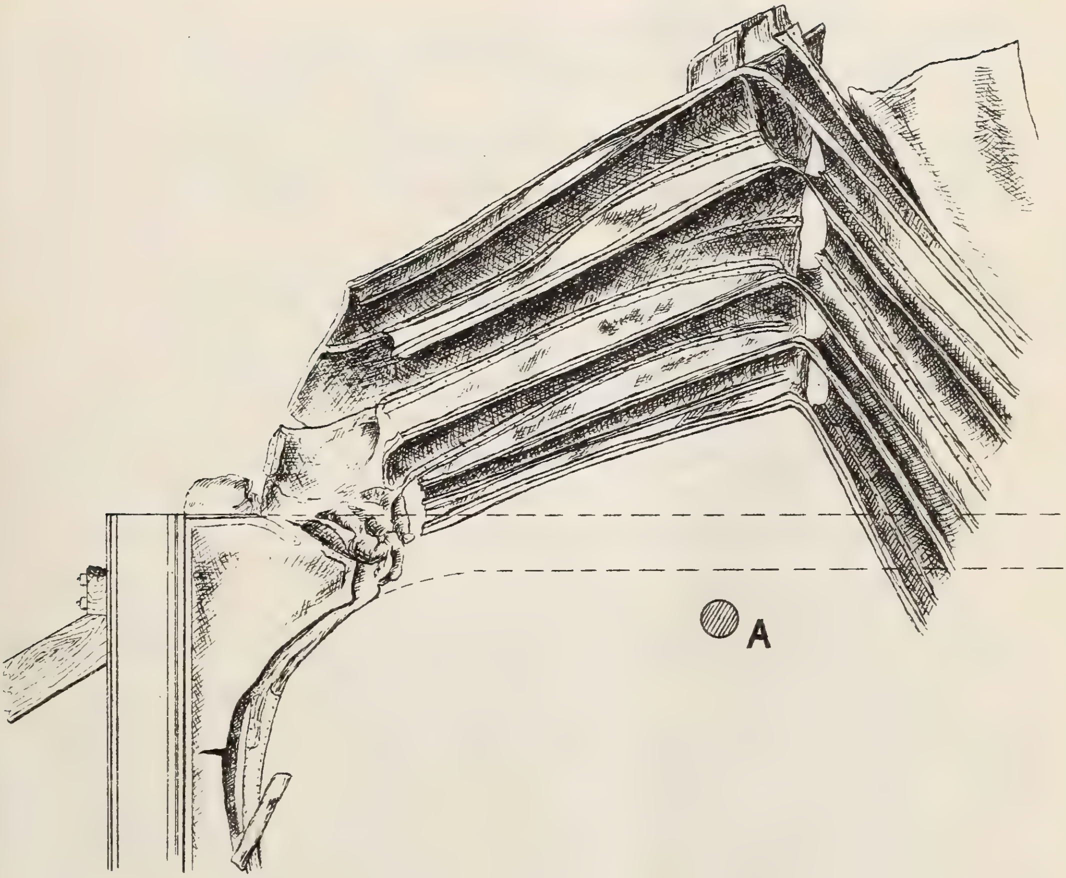


PLATE IX.



5.

WAR SHIPS OF THE FUTURE.*

ABSTRACT OF A PAPER

By Admiral Albini.

Admiral Albini discusses the present position of the naval problem and gives his views thereon, basing them principally on Italian naval experience and experiments.

He has great faith in the torpedo of the present day and in its future development, but places no confidence in torpedo-boats, especially the smaller types.

He is a strong believer in the large first-class battle-ship, and points to the numerous endeavors and subsequent failures in every direction of attempts to achieve great results by small (and supposed economical) means, and when the attempts are not so extreme, partial successes are always followed by needed improvements, which in turn demand increased size; especially is this true in naval construction.

In regard to torpedo-boats he says: To admit that it is the duty of the torpedo-boat to defend the battle-ship is to recognize the impotence of the large ship against her puny adversary, and if in order to exist the ships must depend on the support of these satellites we must confess that their existence would not be justified, and that it would be better to give up building them in the future. How the torpedo-boat can contribute efficaciously to the defense of a large ship he fails, he says, to understand, and the reason is evident. If they keep within the distance of 400 yards from the ship they will in no way impede the attack, seeing that if the enemy's torpedo-boat reaches that limit, even though heavily cannonaded, she will have fulfilled her mission, as she will have been able to launch her torpedo at the striking range. If they keep between 400 and 1,000 yards off they will interfere with the fire of the ship's artillery, which is much more efficacious than that of her satellite, because better distributed, more rapid, and more powerful. If on the other hand, they remain within the orbit of the ship at a distance beyond 1,500 yards, they will afford no protection at all, because though barring one door of approach they will leave a dozen open.

---

* Taken from London Engineering, September 21, 1888.

The torpedo, however, is certain to be much developed, but in proportion as it expands so the advantage of building special vessels for its use will disappear, because the greater space and weight required will not permit the present small dimensions of the vessels to be preserved, and in increasing the size of the ship the necessity will be felt of endowing it with those prerogatives which were sacrificed to the power of the torpedo, and thus by gradual steps the torpedo-boat will be converted into the large ship, using the new form of torpedo under the same conditions as her adversary. That vessel will win the day in which the best combination has been made of all existing weapons, but the torpedo-boat will have then become a battle-ship.

If the question is asked, in what way and for what reason the torpedo itself will be developed, the reply is that the torpedo must follow the analogous progress which led from the 25-ton gun to that of 100 tons. In other words, the eternal struggle between offense and defense will shortly be extended to the torpedo and the hull of a ship. So long as the torpedo was confined to small special craft of slow speed, and consequently its power was not fully shown, it was natural that naval architects should not look upon it as a serious danger; but from the moment when a considerable increase of speed was given both to the weapon itself and the boat which carried it, the necessity of providing defense against it becomes obvious. The struggle has thus commenced. If the latest ships are fairly furnished with protection, we must anticipate that the torpedo will shortly be considerably developed, and will carry charges of 400 pounds and above, and will probably take the form of a penetrating projectile discharged from a subaqueous gun. Whatever increase of power may be given to it the torpedo will remain one of the most formidable weapons of the large ship, but it will certainly never realize the ambitious aim of causing the large ship to disappear. Just as the great rise in the power of artillery led to the entire abandonment of the old form of ship, and from the Monitor type we have progressed to the *Duilio* and the *Lepanto*, so if it is intended to oppose the rising power of subaqueous weapons by ships which are entirely secure against their attack, we must give up the old ideas and seek inspiration for the constructions of the future at a new fount. Battle-ships will have to be built principally with a view to resist with immunity the attack of torpedoes and to avoid being sunk by artillery fire. All other qualities must be satisfied only within restricted limits; that is to say, their measure must be determined in conformity with a not too great extension of size and of cost; those qualities which have been given up in order to secure invulnerability being assigned to special vessels.

Naval opinion will be slow to admit the principle of sacrificing in a battle-ship many qualities which in the present day are esteemed of great value, in order to secure that of unsinkability, but imperious necessity calls for the adoption of this principle inasmuch as the absolutely necessary condition of fighting at sea is that a vessel should float. To this quality, obtained in its most complete form, every other consideration must yield. It is not sufficient solely to prevent the ship going to the bottom, but she must be kept in a condition of complete efficiency, for it will be of little use in a combat to have a ship which, though she does not actually sink, is unable to manœuvre and to fight.

It is certainly by no means an insoluble problem in the present day to construct a ship possessing the required qualities of high speed, invulnerability to the attack of present and future torpedoes, unsinkable by guns, and provided with great offensive power and handiness, though the enormous cost of such colossal structures is a most powerful obstacle to their creation. No nation, however wealthy, could afford to construct its fleets of units, each one of which represents an immense expenditure, even though held superior to many others of inferior power because the invulnerability and power acquired by this expenditure can not guaranty the Colossus against the dangers of disasters at sea, fire, explosions of boilers, and other possible catastrophes, nor against other still more potent agents of destruction which the future may have in store.

Being unable to obtain the necessary complete resistance to sinking when the endeavor is made to fulfill all the other requirements, the necessity will become more and more obvious, as time goes on, of obtaining that quality by sacrificing some other conspicuous characteristic of the ship. Among all the factors which now constitute the military power of a ship that of velocity is without doubt the most prized, and also the one which has been the chief cause of the increase of cost, as well as that which more especially precludes the adoption of a form and construction of the hull which would be better able to resist the offensive development of subaqueous weapons.

It is the velocity therefore which will have to be sacrificed to the advance of the new weapons. This sacrifice will be no doubt strenuously opposed, as speed is always dear to the sailor, accustomed to associate this quality as a leading feature in a good design of ship, but the supreme law of the safety of the ship will force its adoption. Between the alternative of accepting the perpetual danger of being sent to the bottom at any moment or of giving up an excess of speed, no hesitation is possible in adopting this latter solution, however painful the decision may be. This modification in the qualities of a battle-ship will naturally not be by itself a solution of the problem, and it will have to be followed by others, but as the most radical, and perhaps the most contested, its consequences deserve examination.

For battle-ships a sensible excess of speed over an adversary was a distinct advantage, when the guns were ranged along the broadside, because in that case the swifter ship could assume a position from which she could attack the other without being herself attacked. It was also an advantage when the attack by ramming was thought likely to be adopted; but in the present day the system of rotating platforms, which defends equally nearly all the points of the horizon, has caused this advantage to disappear. The modern systems of construction and torpedoes having led to an abandonment of the attack by ramming have also contributed to this result. High speed was retained as a principal defense against the attack of torpedoes, and this was in part justified when the velocity of the torpedoes was only about half that of the ship. At present both the torpedo and the torpedo-boat possess a speed considerably greater than that of the battle-ship, and in consequence speed can no longer be considered as an arm of defense for these last. A superiority of speed is not of very great advantage in the phases of a combat, because the pauses arising from the necessity of manœuvring interfere with its advantage being realized. The superiority of speed, it is true, confers the power of choice in accepting or refusing an action, but the occasions are rare and exceptional when a commander would be justified in making use of the latter prerogative.

A reasonable diminution in speed produces no deleterious consequences in case of an artillery combat, when it is sacrificed to obtain immunity against torpedoes. Between a *Duilio* or an *Italia*, possessing a speed of 15 knots, but liable to be sunk by the explosion of a torpedo, and a ship of nearly equal power and of less velocity but invulnerable to the attack of a dozen torpedoes, the choice can not be doubtful. For that reason sooner or later large battle-ships will have to accept a sacrifice of speed in order to obtain immunity from torpedo attack.

Without doubt many will dispute these conclusions, pointing out that inferior speed leads to impotence, because the quicker ship can always withdraw from the attack of the slower, and that the latter can not escape ramming by the former. These critics forget, however, that speed given to a structure which can be easily sent to the bottom is ephemeral, and that an effective protection against torpedo attack will, in a large measure, be a defense also against ramming. Experience, however, will in the end dispose of these and other objections, as it will demonstrate that superiority of speed, if unaccompanied with invulnerability, is no secure guaranty of being able to take flight, because the high power and accuracy at great distances of the guns of the future will easily clip the wings of the fugitive. If the quicker vessel is reduced to flight on the appearance of the slower one, it signifies that the latter will be master of the field, remaining where it chooses, and where necessary to attain its object, for it can not be contested that a ship should always have some fixed purpose to fulfill, and not alone that of flight. The slow ship, invulnerable to torpedoes, can always force her swift though vulnerable rival to quit any particular spot, whilst the same compulsion can never be exercised upon her, whether she manœuvres furnished with nets or without, and that for reasons which are self-evident.

To sum up, the renunciation of an excess of speed in order to obtain security against torpedoes is the means best adapted for clearly defining the rôle of such battle-ship, and for rendering her more efficacious in the field of action for which she is destined. This difference of speed between the more powerful vessels and those of less size will be accepted in future as the lesser speed of the line-of-battle ship in presence of a frigate, and of the frigate as compared with the corvette, was accepted in former days. Every ship must have some one factor largely developed at the expense of some other less essential for her particular duties. Future fleets must have their Uhlans, their heavy cavalry, and their light artillery, but their real fighting strength will consist of large vessels of reduced speed but unsinkable, and against these the assaults of an enemy who has preferred speed to unsinkability will prove fruitless.

The sacrifice of a portion of the speed will be principally due to the necessity of providing the hull with projecting coffers or plating with free circulation of the water, as a protection against torpedoes; their distance from the hull being determined by the explosive charge of the torpedo. Without discussing their details or form, Admiral Albini holds that this mode of protection, giving free access to water, is the only one on which reliance can be placed. It should project at least 13 feet from the hull.

A reduction in the speed will not suffice by itself to furnish means of giving adequate protection to the hull, and a considerable diminution in the armor now applied to ships will, he considers, have to be effected. With the existing power of guns, which is susceptible of being largely increased, the practical superiority of the gun over armor may henceforth be assumed as incontestable.

Guns are even now in existence which develop an energy of 70,000 foot-tons, and can perforate over 30 inches of the best armor. It is useless to look for adequate protection by increasing the thickness of armor plates. The wisest course is to make use of a large portion of the excessive weight of armor in a manner which shall really contribute to the safety of the vessel.

This reduction will also have its strenuous opponents, as a system of defense which has entailed much time, study, and cost, will not be readily abandoned. The change will consequently be gradual, but in the end the imperious necessity of making the ship unsinkable will force its acceptance.

It is difficult to fix the limit to which this reduction in armor will descend, as it will depend in great measure on the various duties assigned to the vessels and on the development of the smaller classes of guns. Admiral Albini holds that for all parts of the ship above the water-line which are not intended to contribute to the floating power and which must be protected by vertical plating, the thickness of the armor should be determined by the penetrating power capable of being developed in rapid-fire guns, or in light guns of such moderate weight that large numbers can be carried. As it is impossible to associate high penetrating power with rapid fire without a considerable increase of weight and space, he considers the 6-inch gun as about the limit to which this system can be advantageously applied.

Good armor, 12 inches thick, is impenetrable to all the class of rapid-fire weapons, and this thickness for vertical protection should not be exceeded. A ship, secure in this manner against the rapid-fire shell attack, realizes that prudent measure of defense which will justify her undertaking a combat, accepting the risk of some fortunate shot from the big guns paralyzing a portion of her armament. Ships have been exposed to this risk at every period, as one of the hard necessities of warfare. Moreover, it is a danger which may be accepted all the more readily if its acceptance conduces to insure floating power in presence of torpedo attack, for even with all the guns disabled the ship still floats and can manœuvre, steer, and attempt a ram attack, whereas with a large breach in her hull she will sink, notwithstanding that her guns are uninjured.

The experience ot late naval actions tends to confirm that gained in the old wars to the effect that even a heavy and sustained fire produces comparatively small results as far as disabling the guns and their mechanism is concerned. It was the repeated destruction of the gunners of the *Huascar* which brought about her surrender. It is therefore desirable to make the guns of the future automatic as much as possible. By reducing the number of men engaged and substituting machinery, the effect of fire will be less injurious.

The abandonment of excessive thicknesses of armor because incapable of withstanding the power of very large guns, will lead naturally to a disposition to give up the big guns themselves, as beyond the requirements of the case, but there are obvious reasons ágainst this proceeding. Where great power is available it can be employed as needed. If one motive is removed another easily appears. The large gun, as it is able to respond to various requirements, will be retained for a considerable period, though perhaps applied in smaller numbers, as a preventive to a fresh expansion of armor. Under many circumstances one hit from a big gun is more efficacious than a salvo of smaller projectiles, and for high effect at long range no other gun can be substituted, as the reduction in thickness of the armor carried by ships will not bring about a similar reduction in land defenses, where weight is of no consideration.

With the development of new explosives, shell fire against the unarmored parts of a ship will be largely used, and the big gun possesses great power in this direction; the calibres of guns will probably be increased to gain greater effect in this nature of fire. Against the horizontal armor of the future the large gun is the only one which is likely to inflict serious injury, particularly at short range and with plunging fire. On the whole the abandonment of the big gun would be a very ill-advised step.

The reduction in vertical armor for the protection of the guns will enable the horizontal armor to be largely increased. Though hotly disputed, Admiral Albini thinks there can be little question as to the superiority of horizontal over vertical protection.

If the chief object which armor is intended to subserve is that of rendering a ship unsinkable and of maintaining her motive power in full efficiency, both now and also in the future, this result can be attained by horizontal armor, whilst impossible with vertical armor, for the simple reason that one system is penetrable by artillery fire and the other is not; at least within the limits of a reasonable thickness of plating. More than 32 inches of armor is necessary to resist the present guns, and the racking effect of these huge projectiles is such that a very large addition will probably have to be made to the supporting structures in order to prevent the whole side being forced in. The total weight becomes so great as to be inadmissible in practice.

If the vertical armor is perforated the life of the ship is absolutely menaced, not only because the engines, boilers, magazines, and other vital organs are exposed, but from the large openings for ingress of water which will be formed, hazarding the sinking of the ship. A single hit from the 100-ton gun may produce this sudden catastrophe. Nor can it be hoped that the disaster can be avoided by relying on the small chance of a projectile hitting the water-line, such precision being in fact unnecessary. Any one who has witnessed firing trials of the 100-ton gun against armor must be convinced that even striking a yard above the water-line, the injury will extend to a considerable depth below it, for the damage caused is not of the nature of a round hole, but of a wide breach. With horizontal armor, on the other hand, this danger does not exist, as good 4-inch steel plating placed 45 inches below the water-line can not be pierced under the actual conditions of naval warfare, as it is not possible to hit it so as to pierce it. Up to 2,500 yards there is complete immunity to shot, as their path is practically tangential to the surface of the armor. At 2,500 yards the angle of impact would be 5 degrees, insufficient for perforating. Only at 4,000 yards, when the angle of descent becomes 15 degrees, is any danger to be anticipated, but at this distance the attempt to fire at the water-line is out of question, the chance of hitting being 1 in 1,000.

If, in addition, the armor is surmounted with cells 45 inches high, filled with gas coke, it will be able to resist even the fire of the future giant guns, not only on account of the united resistance of the two materials to the energy of the shot, but also on account of the deflecting power which the coke will oppose to the projectile at the angles of descent under which they will strike its surface.

Admiral Albini claims that coke is the best substance for this purpose, as it can be used as a combustible if needed, is of small cost, is not liable to spontaneous combustion when packed in inclosed spaces, has only one-fourth the weight of coal, and he has proved by experiment that it is more resisting than coal to the blow of the shot and tends more to deflect it.

Notwithstanding these advantages it will be impossible to stop the rupture of the underlying armor, if a highly developed curve is given to it instead of being placed flat. The curved protecting deck gives more space for the engines and diminishes the quantity of water which can flow into the cellular spaces, but is easily perforated, and, as regards keeping the vessel afloat, inferior to the flat deck.

In addition to maintaining the power of floating, horizontal protection has the following advantages: Greater security against a ramming blow; the ship is equally protected throughout her whole length; gives greater freedom to the mode of arranging the armor-protected guns; is a measure of defense against high angle fire from land guns; economy in cost of protection; and lastly, less probability of being struck, as the very flat trajectory of modern guns make it easy to hit a vertical target, whilst a very small error suffices to miss a horizontal one.

Objections will be raised to the advantages here attributed to horizontal armor, that if vertical plating is no guaranty against the few powerful guns now existing, it will do better against shells filled with high explosives from smaller guns, which will break up against the armor before penetrating, whereas in the other case they can freely penetrate and develop their full explosive effect.

In reply, Admiral Albini points to the increasing numbers of very heavy guns now carried. The assertion, also, that vertical armor is proof against shells is not entirely the case. With the steel shells now in use armor of considerable thickness can be pierced even by second-class guns, so that, unless recourse be had to complete protection by means of very thick armor, which is inconsistent with the design of a ship of moderate size, all attempts to adopt armor as a defense against modern shells is illusory.

Even if it be admitted that vertical armor is a defense against the shells of second and third class guns, its inferiority of protection as compared with horizontal armor will always be evident, as in the end we are compelled to conclude that a vessel protected with vertical armor will be defended against the fire of small shells, but is exposed to being sunk by big guns, whilst horizontal armor is a complete protection against both modes of attack. In fact, if a shell from a 100-ton gun strikes a little above the water-line, it will in most cases explode in the spaces above the cellular structures without damaging the vital organs of the ship, but if it explodes within the cells, experiment has shown that the effect will be limited to destroying the covering plating of the cells without breaking in the underlying armor. Even if many shot of this nature should strike at different points of the horizontal zone, they would have no influence on the stability of the ship, nor on the proper functioning of the organs of offense, as the cellular belt contains no vital organs and should be considered solely as a zone of support to the structure above it, and in consequence may be frequently hit without being reduced to a condition of not being able to fulfill its function, and being also full of coke, may be pierced in a hundred places without admitting a sufficient quantity of water to do any harm.

In view of the superior powers of resistance to the attack of large and small guns which horizontal armor has been shown to possess, Admiral Albini concludes that it is the form of protection best adapted for use in the future. Another modification which will prove both necessary and advantageous will be that of giving greater manœuvring power, and greater protection to the propellers, against the injuries of torpedoes. The first quality is rendered indispensable in order to remedy in part the defects arising from a reduction in the speed, the other is suggested by the necessity of diminishing the danger of the ship's being disabled by numerous torpedo attacks and of attempts to injure the rudder and propellers. This necessity becomes evident when we consider that the advantages resulting from the prudent principle already carried out for some time of duplicating the most important organs of the ship lose half their value unless the principle is applied also to the propellers and rudder.

A ship which is disabled in her means of propulsion is irretrievably doomed. That this danger is not remote is proved by the fact that the results of firing torpedoes against a ship in motion show that the tendency of errors in aim is to make the torpedoes pass near the stern of the ship, and if they explode there, there can be no doubt that the screws and the rudder will be disabled, as it is very difficult to properly protect this portion of the ship. Admiral Albini considers that the best means of avoiding this danger is to make both ends of the ship exactly alike, with screws and a rudder at each end, which can be used either for increasing the power of manœuvring or as a substitute when one extremity is disabled.

In conclusion he holds that the battle-ship, far from disappearing from the high seas, will become more powerful than ever, subject to the following modifications:

Displacement, approximately the same as that of the latest battle-ships, with symmetrical ends, both provided with rudders and screws.

Great beam, with defense against torpedoes by means of projecting plating, leaving a free passage to the water.

The hull unsinkable by the fire of heavy artillery, by means of horizontal steel armor, 4 inches thick, placed 45 inches below the water-line, and covered by a layer of coke of equal depth.

The armament to consist of four guns of great power placed in barbettes, two at the bow and two at the stern, protected by 12 inches of armor at an angle of 25 degrees, with an external covering of coke a yard thick.

The central battery to be in two tiers placed high above the water-line, and to consist of light artillery made automatic as much as possible; not less than twenty 6-inch, and forty rapid-fire guns, to be carried.

Speed, under six hours' continuous trial, to be about 12 knots.

Admiral Albini's design for a battle-ship is shown by Figs. 1 to 3, Plate X.

Turning to details, Admiral Albini dwells upon the necessity of providing adequate protection for the commander of the ship, which he thinks can best be realized by a number of positions which will conceal the actual place of the captain from the enemy. For second-class battle-ships he suggests a vessel of about 7,000 tons displacement, and mean speed 20 knots, protected by a horizontal deck 2 inches thick placed about 5 feet below the water-line, with coal above in cellular spaces. She should carry two 10-inch guns, one at each end, and forty rapid-fire guns on various superstructures, placed at a great height above the sea, to which he would add the novel disposition of six mortars able to throw to 50 yards distance a charge of explosive gelatine 1,000 pounds in weight.

He finds greater difficulty in determining the form and dimensions of the smaller classes of vessels. He points out that any endeavor to make these vessels capable of engaging larger and more formidable types can only result in failure, and therefore that their offensive powers should be strictly limited to the performance of the duties for which they are intended.

This duty he holds to be principally that of being able to encounter with a great excess of power armed merchant ships. As in this case there will be no armor to penetrate, this excess of power is best attained by the possession of a very large number of guns, ranged perhaps in two tiers, the lower composed of at least twelve guns not exceeding 5 or 6 tons in weight, but of large calibre, not less than 10 inches, specially intended to fire large shells filled with a high explosive. The upper tier to consist of at least twenty rapid-fire guns capable of being used on either broadside. They, as a natural accompaniment, possess high speed and an armored deck below the water-line. In these ships the part above the water will probably be constructed so as to be able to receive a permanent arrangement of nets as a defense against torpedoes. Figs. 4 to 8 on Plate X illustrate two types which he suggests.

Smaller vessels of the same type will also be required. They will differ but little from the others except that they will carry fewer guns.

The dispatch vessel or naval scout will in the future hold a very important position among the smaller class of ships. Many persons think that in the dispatch vessel everything should be sacrificed to attaining a very high speed, and consequently that she should be entirely without armament, since every pound of weight devoted to this interferes with her possessing that fractional excess of speed which will constitute her superiority over her adversary. She should never stop to ac-

PLATE X.

Figs 1, 2, & 3 Battle Ship.
Armament 4 100-ton guns
18 6-in.
28 RF
50 Mach
Total 100 guns

Fig. 1

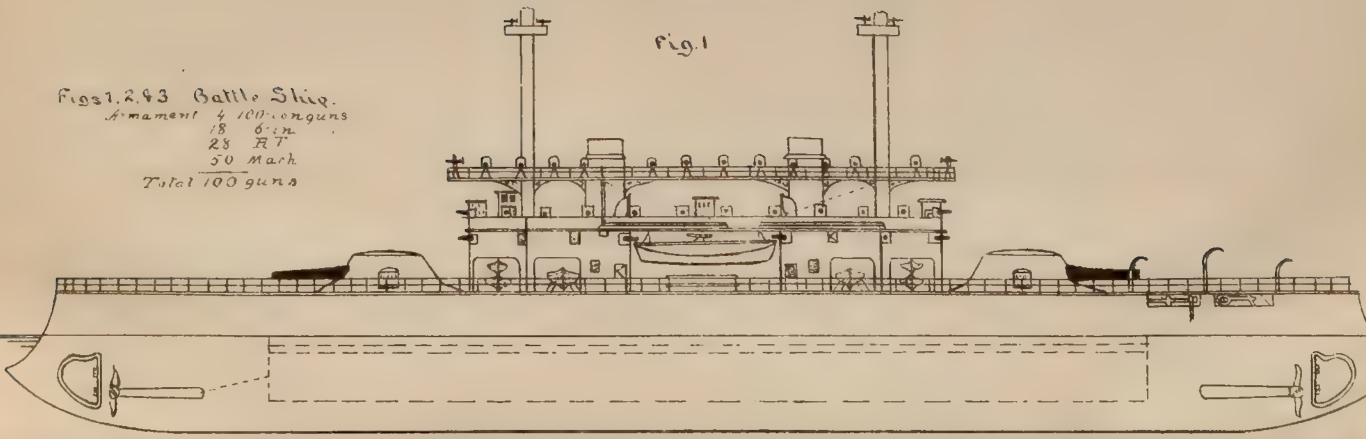


Fig. 2

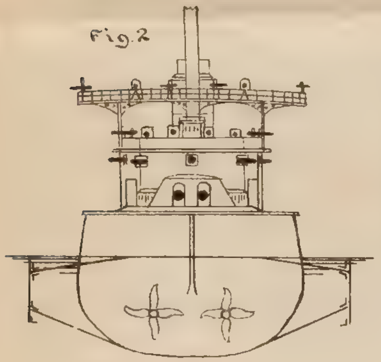


Fig. 3

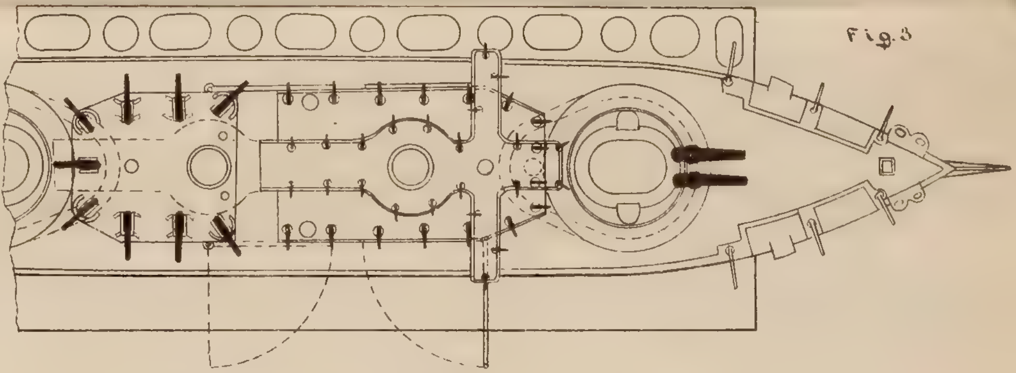


Fig 5

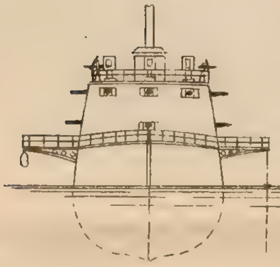


Fig. 4

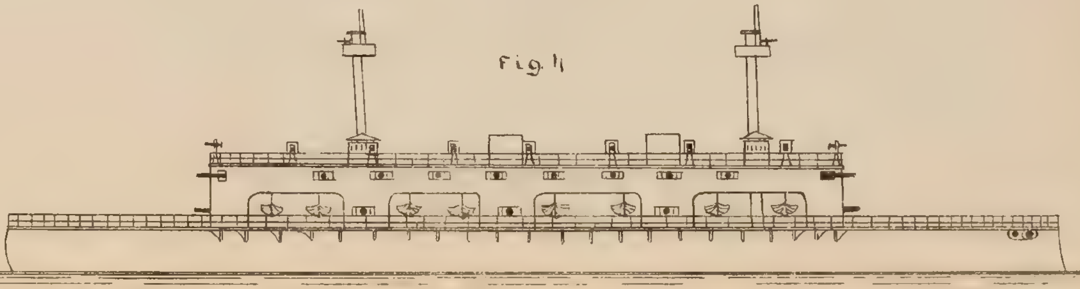


Fig. 6

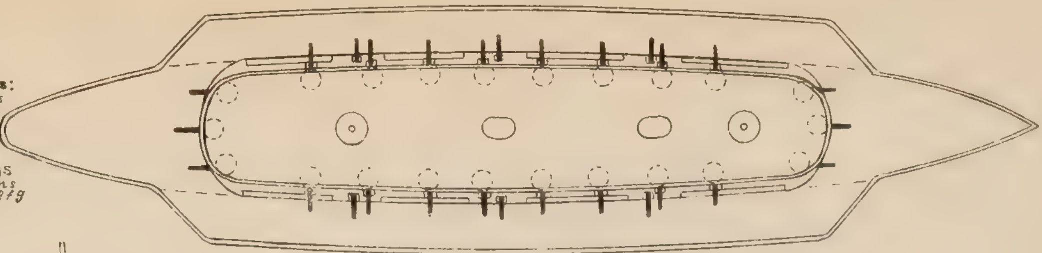


Fig 4, 5, & 6 Cruiser with automatic gun-mountings and a permanent system of nets:
Armament 30 6 in guns
20 57mm Rfg
Total 50 guns

Fig 7 & 8 Cruiser with automatic gun-mount'gs
Armament 28 6 in. guns
12 57mm Rfg
Total 40 guns

Fig. 7

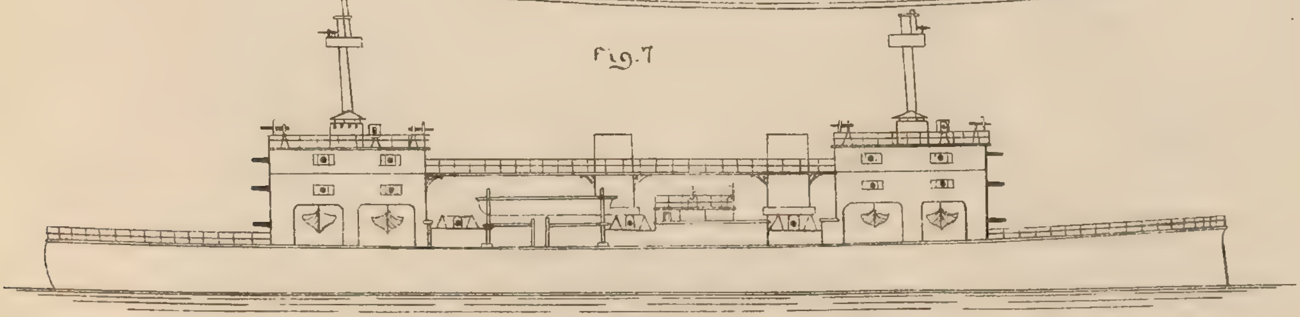
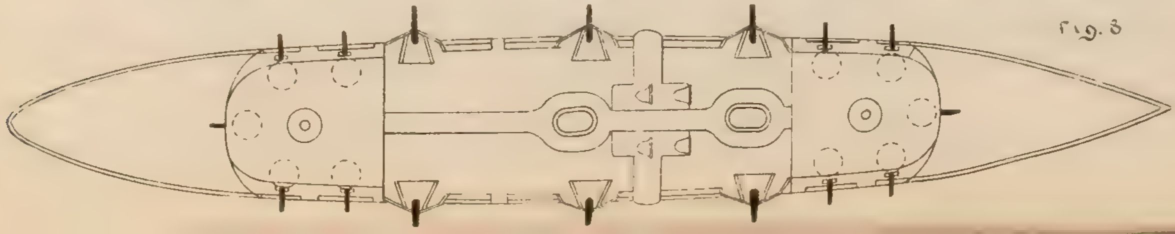


Fig. 8



cept an action, as that would retard her mission, which is to gain and give information. Admiral Albini does not support this view, holding that in practice it would be very difficult to utilize these minute differences, whose effect within the limits of the weight of the armament of such a vessel can be neutralized by the circumstances of the weather, the heel of the ship under the effect of the wind, the length of time she has been under steam, and other very slight causes. To be without any armament would rather impede than facilitate the execution of her duties. If an unarmed scout meets an armed one the latter would prevent her flying by engaging her, and the small superiority of speed would not enable her to escape the projectiles of her adversary. An armament for these vessels of two 36-pounder guns at the bow and two at the stern, mounted together on revolving platforms, would, he considers, fulfill all requirements.

IV.

THE DEVELOPMENT OF THE HIGH-POWER GUN.

By Lieutenant C. E. VREELAND, U. S. Navy.

In this article, descriptive of the development of the high-power gun and its accessories or equipment, and upon which a limit of length has been imposed, it has been found impossible to describe in detail all the various improvements that have taken place within even so brief a period as the past ten years, and some of them it has been found necessary to ignore completely. For example, that phase of development which concerns the treatment of gun metals has been at most merely indicated; under the head of gun-carriages only a brief description of some of the newest types is given; and the evolution of the small-bore magazine rifle has been omitted entirely as opening up too wide a field. Attention has been more especially directed to the improvement of gun designs and slow-burning powders, and to the results obtained with the various high explosives that have been experimented with as bursting charges for shell.

GUNS.

ENGLAND.

The first rifled artillery introduced into the English service were guns of Armstrong design, fitted with the designer's original system of breech-closure, viz., a vent piece locked in position by a breech-screw with a continuous thread. After a brief trial these guns were superseded by others of M. L. type. The cause of the failure of the former, however, must be attributed to the imperfections of the system rather than to the fact of their being breech-loaders. The return to muzzle-loaders was clearly a step in the wrong direction, and after a lapse of some fifteen years England found herself compelled to take up the question of a breech-loading system anew.

The history of the introduction and subsequent development of the present service types may be summarized as follows:

In June, 1879, a committee on ordnance was appointed, under the presidency of the late Maj. Gen. S. E. Gordon, and the instructions furnished it specially urged a full consideration of the relative advantages and disadvantages of the two types—muzzle-loading and breech-loading. (In the annual report of the Director of Artillery for 1878–'79 it had been pointed out that, owing to the increased length of modern guns, breech-loading had become an absolute necessity; and a preference was expressed for the interrupted-screw breech-closure.) The committee must have been unanimous in its conclusions, for it at once launched the Government upon an experimental course of construction of B. L. guns of some of the heaviest calibres then in existence. It first recommended a 12-inch gun of 43 tons, the design of which was furnished by the superintendent of the Royal Gun Factory at Wooiwich; and subsequently designs from the same source for guns of 10.4 and 9.2-inch calibre were appoved, the latter calibre being chosen with a view to enable comparison with the Krupp 24 cm.

Pending this decisive action by the committee, two B. L. guns made at Elswick, of 6 and 8-inch calibre, respectively, were loaned for trial by Sir William Armstrong. The 6-inch proved so satisfactory that the piece was purchased, and an order was given the firm for seventeen additional guns, of which fourteen were subsequently mounted on board H. M. S. *Rover*.

These guns constitute the 6-inch mark I, or 80-pounder (see Plate 1), and were probably the first modern B. L. ordnance introduced in either service.

The 8-inch also was bought and was subjected to trial under direction of the committee, but for some reason no more of this calibre and design were either purchased or made.

The committee was dissolved in March, 1881, and the outcome of its labors up to date may be summed up as follows:

One 12-inch had been completed and had passed a satisfactory proof trial.

One 10.4-inch had passed proof and had subsequently fired some fifty rounds, from which valuable data had been gained.

One 9.2-inch was under construction.

A design had been prepared for a new 6-inch, which was to be greatly superior to the *Rover* gun. (Guns of this design constitute the 6-inch mark II now in service.)

Two 4-inch 25-pounders had been completed and were awaiting trial.

The above were all of Royal Gun Factory design and embodied the following principles: (1) a heavy steel tube reinforced over the rear portion with wrought-iron coils and jacket, the trunnion piece being welded to the jacket; (2) the interrupted-screw breech-closure; (3) the Elswick cup obturation.

Early in 1881 Colonel Maitland, the Superintendent of the Royal Gun Factory, appeared before a newly organized committee to urge a more extensive use of steel in all future designs for high calibres; his views were indorsed by the committee, and before the close of the year some 8-inch guns, entirely of steel, were actually under way. The construction took the form of a heavy steel tube supported by steel coils. No 8-inch guns of this design are at present borne on the service lists, and it is probable that the few that were finished are used for proof firing.

The use of steel coils was contemplated in two other guns designed about this time, viz, a 12 and a 9.2 inch; and in designs for smaller calibres, 6 and 4-inch, forged steel hoops enter into the construction for the first time.

The contract for the 12-inch guns just mentioned was awarded to Sir William Armstrong, who, before commencing manufacture, entered sundry objections to the design; these, coming from so eminent and experienced an authority, were seriously entertained and led to an exhaustive investigation of the whole subject of gun construction, in the course of which the committee called to its aid the advice and opinions of such eminent artillerists, metallurgists, and scientists as General Younghusband, Colonel Maitland (Superintendent Royal Gun Factory), Messrs. Vavasseur, Barnaby (Director of Naval Construction), Firth, Wilson (Cammell & Co.), Brown & Co., Longridge, Siemens, Greenhill, besides others. The conclusions and recommendations of the committee, based upon the mass of evidence submitted, form a small volume, and it is difficult to decide which among them are the most instructive; the following abstracts, however, are thought to embrace the more striking ideas.

(1) The breech screw should engage in the jacket, and not in the tube.

(2) In anticipation of the use of slow-burning powders in heavy guns, the hoops should be carried well forward; they should be made as long as possible consistent with certainty of manufacture.

(3) The superiority of steel over wrought-iron hoops is so marked that the latter material should be entirely abandoned in all future constructions. Coiled steel, although superior to coiled iron, is inferior to forged steel.

(4) The open-hearth process of producing steel presents the greatest possibilities of securing uniform results. The steel should be treated by oil-tempering and annealing.

(5) The de Bange obturation is superior to all other systems adapted to the interrupted-screw breech-closure.

The committee expressed the opinion that the wire-wound system of construction appears to possess certain important advantages over all others, and it recommends that Elswick and the Royal Gun Factory both be called upon to furnish designs for wire-wound guns of 9.2- and 6-inch calibre.

Finally, the committee decided upon a general design for future manufacture, and all guns since made for the English Government have substantially conformed to this design.

The 13.5-inch and 16.25-inch guns shown on Plate 1 illustrate the latest published developments of the Royal Gun Factory and Elswick design, respectively.

It will be seen that in the 13.5-inch there is a liner extending part way up the bore and also an α tube in continuation of the liner to the muzzle. The liner is specially treated with a view to enable it to resist erosion; it is inserted in the tube with a close mechanical fit, without shrinkage, and is kept in place by a screw collar in rear. The α tube is attached to the A tube by the latter being shrunk on, and also by a screw collar in front. The mark I gun has a liner, but no α tube. Where an α tube exists, and its use has become general in the latest marks, it is not deemed necessary to hoop the chase its entire length.*

The manner of locking the joints is not clearly shown in the diagram, but will perhaps be understood from the following brief description: Take, for example, the locking-joint between the jacket and the tube; the former is prepared at the forward end with a row of projections on its inner surface, and the tube is in like manner prepared with a row of projections on its outer surface; in the operation of shrinking on, the projections on one part pass between those on the other, and the jacket is then turned until they are in line, when the intervals are filled in by wedges driven in under pressure.

In the 16.25-inch gun longitudinal strength is provided by shoulders, and movement of the tube is prevented by shrinkage, assisted by a ring of yellow metal run into grooves near the front end of the jacket, the metal, it is said, possessing the property of expanding on cooling. This device is repeated near the front end of the thrust collar hoop.

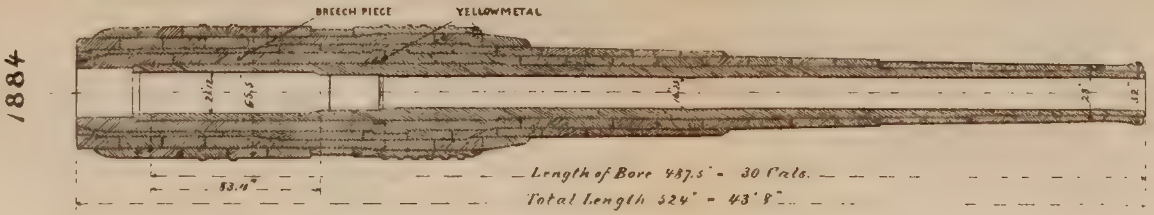
The system of construction of the Maitland 9.2-inch wire-wound gun recently finished at Woolwich is as follows: The tube is made much thicker over the chamber than elsewhere, and the thick part is turned down in steps towards the centre. Over the hollow thus formed, and which extends nearly half the length of the gun, is coiled wire ribbon, one-fourth by one-eighth inch in section, of a tensile strength of 80,000 pounds to the square inch; the ends of the wire, after heating in a blowpipe, are bent to the proper direction and secured by screws and plugs. When the hollows in the tube have been quite filled, the trunnion-ring and jacket are shrunk on over the wire and are locked together by a locking-joint. The total weight of the gun is 22 tons—exactly that of the service gun; but it is expected that the wire gun will be able to fire

---

* It was stated last year in the House of Commons that of twenty-six 9.2-inch guns subjected to proof trial five had split their liners; the same year recorded the rupture of the "A" tube of a 10-inch gun just at its juncture with the liner; and later still it was reported that two of the 13.5-inch guns had been disabled through failure of their liners; from all of which it would appear that the latest English guns are not altogether satisfactory, and, in fact, in a statement explanatory of the naval estimates for 1889–'90, the First Lord of the Admiralty intimates that a change in design has been effected which will eliminate this source of failure in the heavy guns of the future.

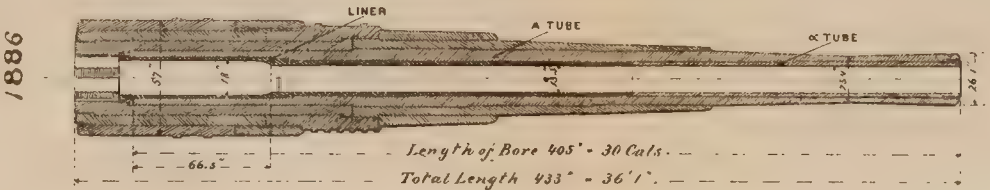
16.25 INCH B.L. GUN 111 TONS.

E.O.C. CONSTRUCTION, ALL STEEL.

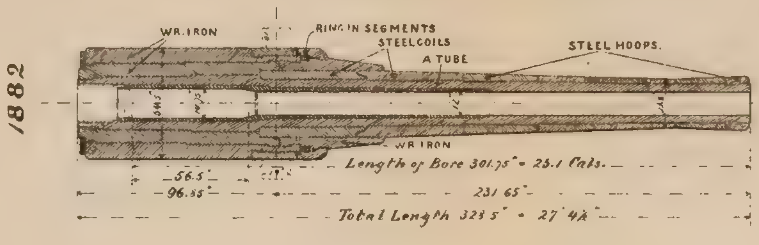


13.5 INCH B.L. GUN 67 TONS MARK II.

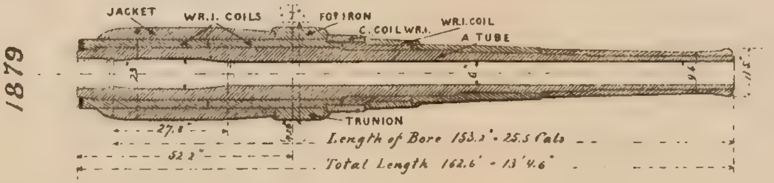
ALL STEEL.



12 INCH B.L. GUN 47 TONS MARK I.



6 IN B.L. GUN, 81 CWT (80 PR) E.O.C. CONSTRUCTION.



a charge of 270 pounds of brown powder (it has done so on at least one occasion), whereas the service gun in limited to 175 pounds.

In the accompanying table, as well as in those of French and German guns, on pages 142 and 145, it has been sought to illustrate further, by the aid of figures, the course of progress outlined in the text.

Date of design (approximate).	Gun.		Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought-iron.
	″		*Tons.*	*Inches.*	*Calibres.*	*Pounds.*	*Pounds.*	*Foot-seconds.*	*Foot-tons.*	*Inches.*
1884	16.25	mark I....	111	524.0	30	850	1,800	2,148	57,580	34.1
1886	13.5	mark II...	67	433.0	30	520	1,250	2,025	35,540	29.4
1886	12	mark V ...	45	328.5	25.2	295	714	1,892	17,720	22.2
1886	10	mark II...	29	342.4	32.0	250	500	2,100	15,290	22.5
1886	9.2	mark V ...	22	310.0	31.5	175	380	2,065	11,235	20.2
1881	9.2	mark I....	22	255.8	25.6	160	380	1,835	8,873	18.0
1886	8	mark VI ..	14	254.5	29.6	118	210	2,200	7,048	17.2
1883	8	mark III..	14	222.5	25.6	100	210	1,960	5,594	15.3
....	6	mark V ...	5.0	195.3	30.6	....	100	1,920	2,556	12.0
1879	6	80 pr......	4.0	162.6	25.5	34	80	1,880	1,961	10.6

FRANCE.

Up to 1875, or perhaps a little later, the heavy artillery of France was composed of cast-iron guns hooped with steel, some without liners, others with steel liners extending about half way up the bore, and others still with liners extending the entire length of the bore, all indicating a persistent effort to perpetuate the use of cast-iron in some part of the construction. On the other hand the French had perfected, as early as 1866, the interrupted screw breech closure and had adopted an excellent system of obturation; the axial vent and safety firing arrangement were added in 1874.

Some data relative to the heaviest guns of these types are given in the accompanying table:

Calibre and model.	Calibre in inches.	Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought iron.
		Tons.	*Inches.*	*Calibres.*	*Pounds.*	*Pounds.*	*Foot. seconds.*	*Foot tons.*	*Inches.*
27 cm., model 1870.	10.81	22.8	211.8	18.0	92.6	476.2	1,423	6,686	14.4
24 cm., model 1870..	9.45	15.3	194.5	18.1	61.7	317.5	1,443	4,584	12.8
19 cm., model 1870*.	7.64	7.8	163.4	19.8	33.1	165.3	1,469	2,474	10.5

* The U. S. converted 8-inch M. L. R. has exactly the same weight as this gun, 7 foot-tons more total energy, and 0.2 inch less perforation. This comparison affords a very fair idea of the power of the entire series of the 1870 model.

The all-steel construction was introduced in the face of decided protests from some of the leading French artillerists of the day,* but it was introduced, nevertheless, and about 1875 designs were prepared for all-steel guns of 27-, 34-, 37-, and 42 cm. calibre, the last named being the heaviest gun in the French service to-day.

Since then no other material has been employed in the construction of any naval gun, although the manufacture of cast iron coast-defense ordnance was continued to so recent a date as 1881.

The salient features of the original 1875 model are the heavy body, composed of two parts of about equal weight united by a hook scarf; the tube, which extends from the obturator seat to the muzzle, some two or three calibres beyond the body; and the hoops, in two or three layers (according to the calibre), which re-enforce the body to a short distance in front of the trunnions. The body is of steel, forged, but not tempered, and measures about 0.75 calibre in thickness; the tube, also of forged steel, but tempered in oil, is about 0.25 calibre thick; the hoops, of puddled steel, are about 0.6 calibre thick. A longitudinal section of the interior displays an enlarged obturator seat; a long, cylindrical powder chamber of diameter but little greater than the calibre; a short conic frustum connecting powder and shot chambers; and a slightly coned shot chamber sloping into the bore.

The results of the trials of the first guns of this model were not altogether satisfactory. At the third round from the 34 cm. No. 4 the breech blew out,† the rupture occurring in the forward part of the screw-box. The weight of charge was 247 pounds, and the crusher gauge indicated a pressure of 16.8 tons. A second gun, firing a charge of 277.8 pounds, was spiked through the threads on the plug striking into the screw-box. Four other guns which had fired from six to twenty-one rounds each with the same weight of charge suffered in the same manner, although not to the extent of disabling.

A committee appointed to inquire into the cause of these mishaps reported that although the test pieces cut from the forgings before manufacture had fully met the requirements of the specifications, those cut from near the injured parts fell much short of them. It also stated that the design was defective, and recommended the adoption of the device (*virole*) shown in the section of the 34-cm. gun on Plate 2, viz., a sleeve which screws on to the tube and locks into the body of the gun, and in which is lodged the breech-plug. This recommendation was carried into effect in all new guns and, where possible, in those already under construction.

---

* Colonel de la Rocque, in a study entitled La Résistance des Canons Rayés, published in 1885, expresses himself on this point about as follows: The substitution of steel of the quality obtainable at Ruelle at that time (about 1875) added no appreciable strength to the guns of the navy, while it diminished the safety of firing. The General Inspection was convinced of this, but it no longer had the direction of the construction of the marine artillery; it had simply the right to express its opinion. The entire marine protested bitterly against the change. * * * But their protests availed nothing, and it was decided that all navy guns of heavy calibre should thereafter (1875) be made entirely of steel. Cast-iron was relegated to the coast defense.

† This is precisely the nature of the accident that happened to the Duperré's gun, which, it appears, was one of the guns so far advanced towards completion that the modification described farther on could not be introduced. For particulars of the Duperré explosion see the Notes on Ordnance, p. 396.

The first 42-cm. gun gave way on proof firing along the chase, just at the point where the body ceases to support the tube. This gun was of Siemens-Martin steel, and its failure was attributed by the authorities to the same causes as those which operated in the case of the 34cm. It was stated that not only was there a want of uniformity in the different forgings, but also that the same forging did not exhibit the same qualities throughout. The only conclusion to be drawn is, that the French at this period were unable to produce steel of a quality suitable to enter into the construction of guns of large calibre.

Upon the introduction of slow-burning powders many of the guns of the 1875 model were re-chambered to take a heavier charge of the new powder. No considerable enlargement could be made in the diameter of the chamber without materially weakening the walls of the gun; consequently it had to be made in the direction of the length, and the enlargement in this direction was limited by the necessity of preserving a sufficient length of travel of the projectile to insure complete combustion of the charge before the shell left the bore. It was found, however, that with judicious air-spacing the increased charge gave in some cases as much as 90 and 100 foot-seconds greater velocity, without material increase of pressure.

In 1881–'82 designs were prepared for guns of all service calibres from 65 mm. to 34 cm. inclusive, in which the length of bore, save in a few guns intended for special purposes, is increased to 28 calibres, from about 19 calibres in the model just described. These guns constitute the 1881 model and are the most approved pattern actually in service; they are hooped but not tubed (see plate 2), and the material used throughout is steel, forged and oil tempered. In the interior are preserved the same characteristics as those described above; but the chamber is of much greater diameter than formerly, and the final twist of the rifling is increased from 4° to 7°. It will be seen that while all parts unite to resist the transverse stresses, the longitudinal stress is borne by the tube alone.

In the proof trial of the 27-cm. gun the mean of eight rounds with 201.7 pounds of prismatic brown powder and a 476.2-pound projectile gave a velocity of 2,000 foot-seconds, the maximum indicated pressure being 16 tons. With the same charge and a 397-pound projectile the velocity reached 2,139 foot-seconds, the pressure being the same as before. In the test for endurance 383 rounds were fired, of which 328 were with service weights of charge and projectile; the bore showed considerable erosion, but not enough to impair sensibly the accuracy of fire.

The trial of the 24-cm. gun was made at Gâvre during the year 1886. With a charge of 155.2 pounds of prismatic brown powder and a 317.5-pound projectile a mean velocity of 2,034 foot-seconds was obtained, the pressure being 14.1 tons. In the test for endurance the gun withstood 350 rounds, of which 273 were with service charge, without sensible loss of accuracy.

The experimental 16-cm. gun has fired 539 rounds, in which the pressures varied from 11.4 to 17.8 tons. The life of this gun has been provisionally fixed at 450 rounds with service charge and projectile.

Certain difficulties having been encountered in the manufacture of guns of large calibre of the 1881 model, notably in obtaining an equable temper in the large masses of steel called for by the design, a new design was proposed for the 27-cm. and superior calibres, which it was thought would obviate these difficulties, and the guns made in accordance therewith will be known as the model 1884. The guns are tubed; a sleeve similar to that found in the later guns of the 1875 model screws onto the rear end of the tube and accommodates the breech-plug; the tube is hooped to within about 8 calibres of the muzzle; a jacket about 16 calibres long is shrunk over the first layer and is in turn reinforced with a second layer of 5 hoops, one of which carries the trunnions. It is not known that any guns of this model have yet made their appearance on the proving grounds. It is expected that they will use the same charge and projectile as the corresponding calibres of the 1881 model.

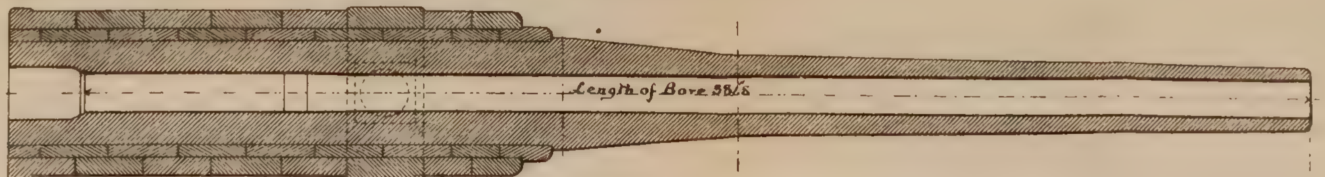
An experimental 24 cm. of 42 calibres length has been completed practically on the above design, except that it is hooped to the muzzle, and it is understood that other calibres of the same relative length are under construction.

Comparative table of French guns of recent models.

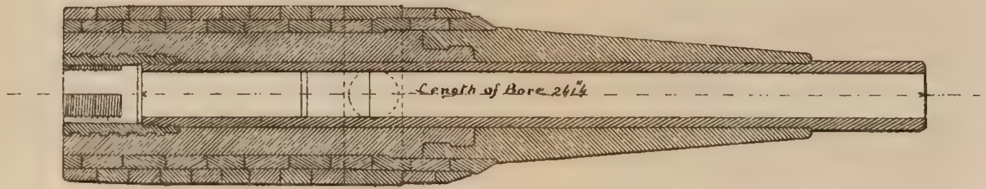
Model.	Calibre.	Calibre in inches.	Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought iron.
			Tons.	*Inches.*	*Calibres.*	*Pounds.*	*Pounds.*	*Foot-seconds.*	*Foot-tons.*	*Inches.*
1875.....	42 cm	16. 54	74. 2	389. 8	22. 0	595. 2	1, 719. 6	1, 692	34, 140	26. 1
1875-'79 .	37 cm	14. 57	74. 8	440. 3	28. 5	617. 2	1, 234. 6	1, 968	33, 160	27. 4
1881.....	34 cm	13. 39	51. 9	404. 1	28. 5	337. 3	926. 0	1, 968	24, 870	24. 8
1875.....	34 cm	13. 39	47. 5	263. 8	19. 6	257. 9	926. 0	1, 594	16, 320	20. 1
1881....	27 cm	10. 81	28. 2	325. 7	28. 5	200. 6	476. 2	2, 034	13, 660	20. 5
1875*....	27 cm. No.1	10. 81	27. 4	231. 1	19. 7	165. 3	476. 2	1, 735	9, 940	17. 5
1875.....	27 cm. No.1	10. 81	27. 4	231. 1	19. 7	136. 7	476. 2	1, 640	8, 881	16. 7

* Modified.

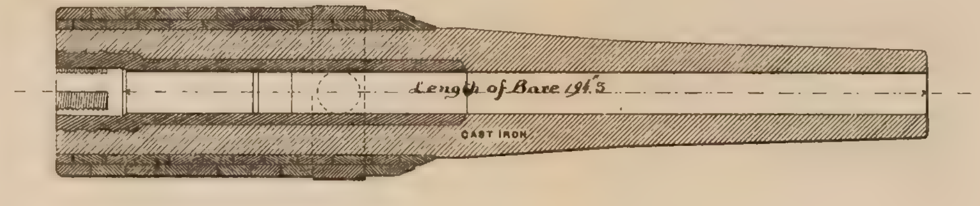
34-cm. LONG, MODEL 1881.
ALL STEEL



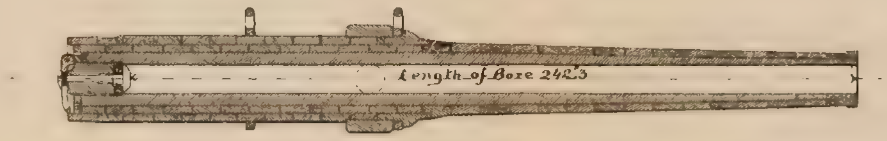
34-cm. MODEL 1875.
ALL STEEL



32-cm. MODEL 1870.



240-mm. DE BANGE, ARMY GUN.
ALL STEEL



GERMANY.

The history of the development of ordnance material in Germany is the history of the development of the Krupp establishment, and the latter, for the purposes of this article, may be looked for in the reports of the Meppen firing trials.

The condition of affairs in the year 1878 will be taken as a starting point, for since then the advance has been so marked that it may fairly be said that in comparison with the Krupp guns of to-day those of ten years ago are almost as obsolete as the English muzzle-loaders. A comparison of the heaviest Krupp gun actually in service in 1878, the 30.5 cm., with the Woolwich 12.5-inch M. L. is presented herewith to bear out this statement.

	Weight.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought iron.
	Tons.	*Cals.*	*Pounds.*	*Pounds.*	*Ft.-secs.*	*Ft.-tons.*	*Inches.*
Krupp 30.5^cm^.	35.4	18.9	202.8	725.3	1,712	14,740	20.2
Woolwich 12.5 inch.	38.0	16.0	210.0	820.0	1,575	14,105	19.5

The construction in vogue prior to 1878 and the later or jacketed construction are both illustrated on plate 3; it is only necessary to add that the material in both cases is crucible cast-steel forged under the hammer.

It was in the summer of 1879 that Krupp startled artillerists with the most magnificent series of experiments ever witnessed, the chief event being the trial of the new 40 cm. 71-ton gun, the particulars of which, as well as of the subsequent trials, are given as follows:

Calibre, 40-cm.; weight, 71 tons; length of bore, 21.8 calibres. With a charge of 485 pounds of prismatic black powder and a 1,715-pound projectile, a velocity of 1702 foot-seconds was recorded, the crusher gauge indicating a pressure of 20.9 tons.

In August, 1882, in a series of nine rounds with charges varying between 397 and 463 pounds of different varieties of powder and projectile weighing 1,764 pounds, the velocities ranged between 1,479 and 1,692 foot-seconds, the maximum pressure being 17.3 tons.

The accuracy of the gun was remarkable; at a range of 2,734 yards (the greatest one available for tests of this kind) six shots were placed within a vertical rectangle measuring less than 18 inches in height by 71 inches in width.

It was a habit ten years ago to compare the proof performance of this gun with that of the Woolwich 80-ton muzzle-loader, and the comparison made then is reproduced now. A comparison is also instituted between the Krupp gun and the Armstrong 100-ton muzzle-loader when fired under service conditions:

	Krupp 70.9-ton B. L.	Woolwich 80-ton M. L.	Krupp 70.9-ton B. L.	Armstrong 102.2-ton M.L.
Calibre .... inches..	15.75	16	....	17.72
Length, total .... do....	393.7	321	....	391.8
Length of bore .... calibres..	21.8	18	....	20.5
Projectile .... pounds..	1,715	1,728	1,708.5	2,000
Charge .... do....	485	445	451.9	450
Velocity .... foot-seconds..	1,702	1,657	1,647	1,548
Energy, total .... foot-tons..	34,450	32,900	32,140	33,230
Energy, per ton of gun .... do....	485	413	453	332
Perforation of wrought iron. inches..	26.9	26.1	26	24.9

Two years later, in 1881, Krupp advanced at a step from guns of 25 to guns of 30 and 35 calibres total length. The new guns do not differ in the method of construction from the 40-cm. of 71 tons; that is, they all have a jacket in which is lodged the cylindro-prismatic wedge, and the heavier calibres are invariably hooped to the muzzle. The interior presents some slight modifications: the shot chamber, which in the old pattern was cylindrical and connected with the bore by means of a short frustum of a cone, is now conical and slopes into the bore gradually; the rifling has an increasing twist of from 50 to 25 calibres instead of the former uniform twist of about 45 calibres.

Following are abstracts of the proof trials of some of these guns:

35.5 cm., L/30;* weight, 57.6 tons.

The firing took place during the spring of 1882. With an 1,157.4-pound projectile and charges varying from 220.5 to 319.7 pounds of different varieties of powder, the maximum velocity obtained was 1,761 foot-seconds; the pressure occasionally reached 19 tons to the square inch.

30.5 cm., L/35; weight, 48.4 tons.

Weight of projectile, 1,003 pounds. One hundred and fourteen rounds were fired with charges varying from 310.8 to 374.8 pounds; two rounds were with the maximum charge, and ten others with a charge of 357.1 pounds. The velocity at one time reached 2,250 foot-seconds, the corresponding pressure being 19.5 tons; it frequently exceeded 2,065 foot-seconds, with pressures of about 18.4 tons.

28 cm., L/35; weight, 36.8 tons.

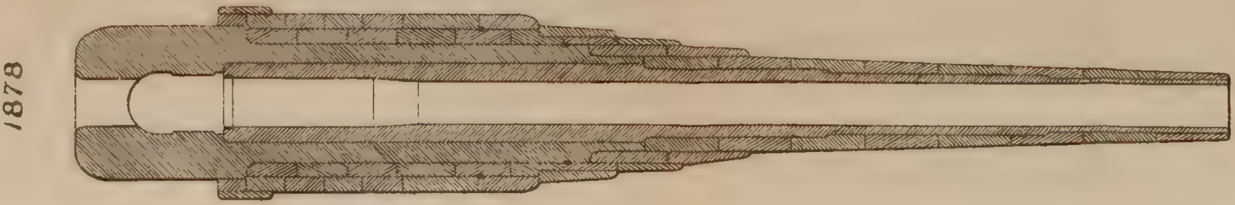
The firing took place during the months of May and June, 1882; in all one hundred and twenty-nine rounds were fired. With a charge of 253.5 pounds and projectile weighing 760.6 pounds, a velocity of 1,739 foot-seconds was recorded, the maximum pressure being 19.5 tons. Five rounds fired at an elevation of 17° 15′ gave a mean range of 11,200 yards. The mean deviation for the same series was, longitudinal, 175 feet; lateral, 15.7 feet. The firing was resumed in August, 1883, for the purpose of comparing different varieties of powder, when, with the same projectile and a 275.6-pound charge, the velocity reached 1,850 foot-seconds.

---

* Total length, 30 calibres.

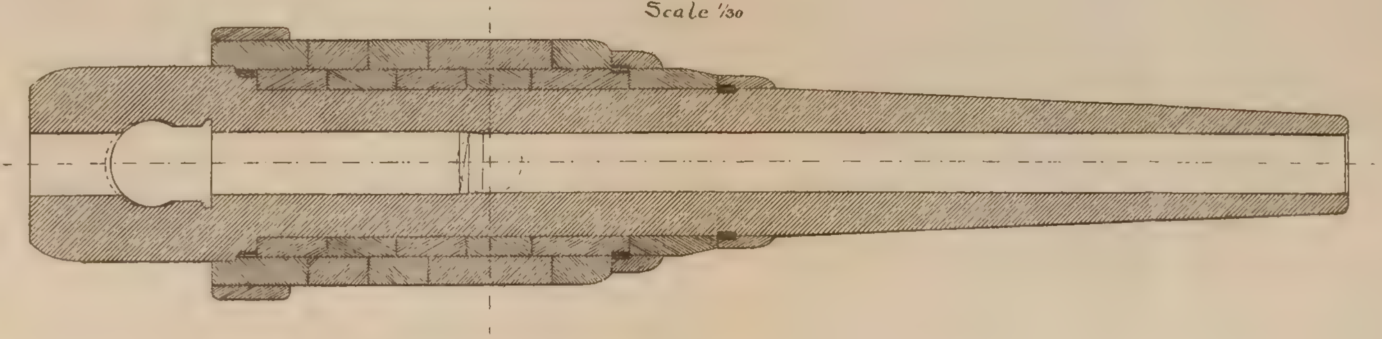
40-cm., JACKETED & HOOPED.

Scale 1/60



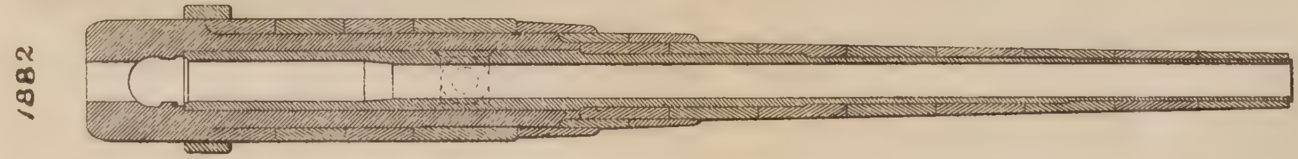
26-cm., LONG, HOOPED.

Scale 1/30



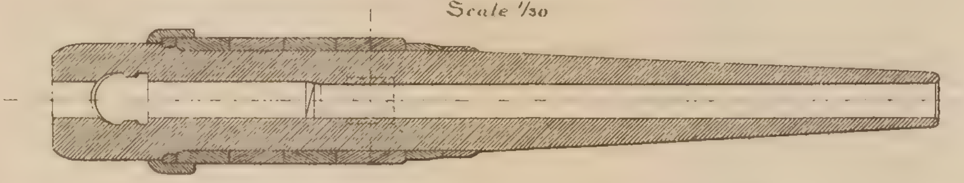
15-cm., L/35.

Scale 1/30



15-cm., LONG, HOOPED.

Scale 1/30



Krupp no longer publishes the sections of his guns, and the dimensions and disposition of the parts in the 40-cm. and 15-cm. L/35 are not to be accepted as strictly accurate. The diagrams here given have been constructed in accordance with the published outlines of the guns and generally accepted theories.

26 cm., $^{L}/_{35}$; weight, 27.2 tons.

The best of six rounds, with a 608.5-pound projectile and 191.8 pounds of powder, gave a velocity of 1,801 foot-seconds, the gauge indicating 16.8 tons pressure.

24 cm., $^{L}/_{35}$; weight, 20.5 tons.

Eight rounds were fired with a uniform charge of 150 pounds of brown powder and a 476-pound projectile; the highest velocity recorded was 1,794 foot-seconds, and the maximum pressure 15.5 tons.

15 cm., $^{L}/_{35}$; weight, 4.7 tons.

Twenty rounds were executed with uniform charges of 37.6 pounds prismatic black powder and projectile 3.35 and 4 calibres long, both weighing 112.2 pounds. The velocity of the 3.35 calibre projectile was 1,764 foot-seconds, that of the 4-calibre projectile 1,748 foot-seconds, the pressures being 16.5 and 16.2 tons, respectively. The range obtained under an angle of fire of 20° was 9,740 yards.

The heaviest guns in existence are the four Krupp 40 cm., $^{L}/_{35}$, made for the Italian Government. Three of these have been delivered, the fourth one being retained for a time to continue experiments with powder. The acceptance trials took place during the autumn of 1886. The terms of the contract required that one gun of the four should fire at least fifty rounds with projectiles of 2,028 pounds weight, to which should be given a muzzle velocity of 1,804 foot-seconds. Ten of the fifty rounds were to be fired at a target distant 2,734 yards, and it was stipulated that all of the shot should fall within a vertical 10.66-foot square. All the requirements were satisfactorily fulfilled, and the guns were accepted. The firing was continued up to eighty-two rounds. Round eighty-one was made with an 864.6-pound charge, when the velocity was increased to 1,876 foot-seconds, the pressure rising to 18.9 tons. In the round preceding the gauge indicated 19.5 tons. The gun held back for further experiment has up to latest published accounts fired two hundred rounds.

Comparative table of Krupp guns of different models.

Date of design (approximate).	Calibre.		Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought iron.
	Cm.	*Inches.*	*Tons.*	*Inches.*	*Cal.*	*Pounds.*	*Pounds.*	*Ft. secs.*	*Ft. tons.*	*Inches.*
1882	40	15.75	119.0	551.2	31.7	727.5	2028.2	1,804	45,770	30.9
1878	40	15.75	70.9	393.7	21.8	451.9	1,708.5	1,647	32,140	26.0
1882	35.5	13.98	75.3	488.2	32.0	463.0	1,157.4	1,984	31,590	27.3
1877	35.5	13.98	51.2	346.5	21.8	253.5	1,157.4	1,640	21,585	22.6
1882	30.5	12.01	48.4	421.2	32.0	357.2	1,003.0	1,853	23,880	25.6
1876	30.5	12.01	35.4	263.8	18.9	202.8	725.3	1,712	14,740	20.2
1882	21	8.24	13.0	288.6	32.1	103.6	308.6	1738	6,464	16.2
1876	21	8.24	9.8	185.3	19.6	41.9	217.2	1,463	3,224	11.5
1882	15	5.87	4.1	176.0	27.2	33.1	112.4	1,624	2,056	10.9
1868	15	5.87	3.45	128.7	19.1	13.2	78.3	1,358	1,001	7.7

UNITED STATES.

Five years ago the main batteries of United States war vessels were composed of (1) Dahlgren smooth-bores, chiefly of the IX-inch calbre; (2) muzzle-loading guns of the Parrott type, viz., a cast-iron body reinforced over the powder-chamber with a wrought-iron hoop; (3) 8-inch M. L. rifle converted on the Palliser system from the XI-inch smoothbore; and (4) 60- and 80-pounder B. L. rifles resulting from the conversion of the above-mentioned Parrott M. L. guns.

Some of the particulars of these guns are given in the accompanying table of—

Guns in service in 1884.

	Weight.	Total length.	Charge.	Projectile.	Total energy.	Perforation of wrought iron.
	Tons.	*Inches.*	*Pounds.*	*Pounds.*	*Foot-tons.*	*Inches.*
IX-inch S. B	4. 0	132	10	70	847	....
8-inch M. L. R	7. 8	160	35	180	2, 481	10. 3
100-pounder M. L. R	4. 3	154	10	100	809	6. 6
80-pounder B. L. R	4. 5	139	8	80	696	6. 2
60-pounder B. L. R	2. 4	112	8	48	562	6. 1

The advance that has been made in this brief period of five years can best be shown by a comparison of the above with the following data of—

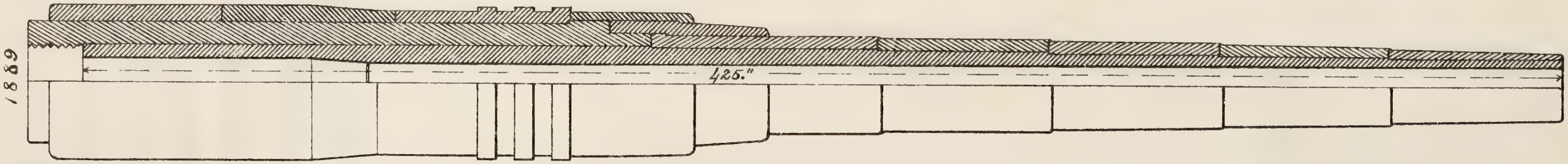
Guns in service or under construction in 1889.

	Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Total energy.	Perforation of wrought iron.
	Tons.	*Inches.*	*Calibres.*	*Pounds.*	*Pounds.*	*Ft. secs.*	*Foot-tons.*	*Inches.*
12-inch B. L. R	45. 2	441	35	425	850	2, 100	25, 990	26. 7
10-inch B. L. R	24. 1	329	31	250	500	2, 000	13, 870	21. 3
8-inch B. L. R	13. 1	304. 5	35	125	250	2, 100	7, 645	17. 9
8-inch B. L. R	12. 3	258	30	125	250	2, 000	6, 934	17. 0
6-inch B. L. R	4. 9	196	30	50	100	2, 000	2, 774	12. 5
5-inch B. L. R	3. 3	182	34	30	60	2, 100	1, 835	11. 2
5-inch B. L. R	2. 8	162	30	30	60	2, 000	1, 664	10. 6
4-inch R. F	1. 7	164	40	12	36	2, 000	999	9. 2

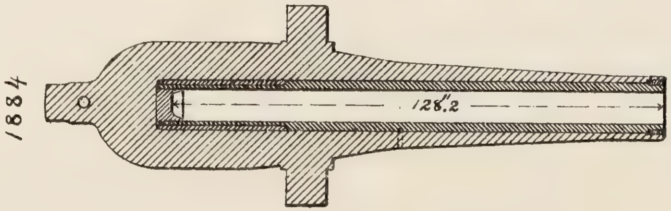
The following table has been arranged with a view to afford a comparison of the powers of the guns of different nations by means of a statement of the muzzle energies expressed in ton units of the weight of gun. Such a factor is not a measure of the actual power of the gun, because the internal stresses are kept well within the limits of

PLATE 4.
United States.

12 INCH B.L.R., MARK I.



8 INCH CONVERTED M.L.R.



safety, and a test which fails to try the ultimate strength of the gun obviously fails to afford an exact basis for comparison; it serves the present purpose, however, where the object is to show which gun of a given calibre is capable of doing the most work per ton of weight when fired under service conditions. A column of penetrations has been added, the values of which have been computed from Noble's formula, $p = \left(\frac{\varepsilon}{.86}\right)^{\frac{1}{2.035}}$, in which p is the perforation of unbacked wrought-iron in inches and ε the value in the column "energy per inch of circumference of shot." Although the formula is not an exact one for all calibres it answers for a comparison of the kind proposed.

Nation.	Gun.	Calibre in inches.	Service.	Maker.	Weight.	Total length.	Length of bore.	Charge.	Projectile.	Muzzle velocity.	Muzzlo energy.			Perforation of wrought-iron.
											Total.	Per ton of gun.	Per inch circumference of shot.	
					Tons.	*Inches.*	*Calibres.*	*Pounds.*	*Pounds.*	*Foot-seconds.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons.*	*Inches.*
Italy	431-mm.	17.0	N.	Armstrong..	104.3	486.6	27.0	771.6	2,001.7	1,814	45,675	438	855	29.7
France	42-cm.	16.54	N.	Government.	74.2	389.8	22.0	595.2	1,719.6	1,692	34,140	460	657	26.1
England	16″.25	16.25	N.	Armstrong..	111	524.0	30.0	850.0	1,800.0	2,148	57,580	519	1,128	34.1
Italy..........	40-cm.	15.75	L.	Krupp	119	551.2	31.7	727.5	2,028.2	1,804	45,770	385	925	30.9
Germany	40-cm.	15.75	L.	Krupp	70.9	393.7	21.8	451.9	1,708.5	1,647	32,140	453	650	26.0
France	37-cm.	14.57	N.	Government.	74.8	440.3	28.5	617.2	1,234.6	1,968	33,160	443	724	27.4
Spain	35.5-cm.	13.98	L.	Krupp	75.3	488.2	32.0	463.0	1,157.4	1,984	31,590	421	719	27.3
Italy...........	343-mm.	13.5	N.	Armstrong..	68	431.9	30.0	628.3	1,247.8	2,020	35,310	519	832	29.3
England	13″.5	13.5	N.	Government.	67	433.0	30.0	520.0	1,250.0	2,025	35,540	530	838	29.4
France	34-cm.	13.39	N.	Government.	51.9	404.1	28.5	337.3	926.0	1,968	24,870	479	591	24.8
Spain	32-cm.	12.6	N.	Government.	48.4	463.8	34.9	485.0	1,058.2	2,050	30,840	637	779	28.4
Spain	30.5-cm.	12.0	L.	Krupp	48.4	421.2	32.0	357.2	1,003.0	1,853	23,880	493	633	25.6
England	12″	12.0	N.	Government.	45	328.5	25.2	295.0	714.0	1,892	17,720	394	470	22.2
United States..	12″	12.0	N.	Government.	45.2	441.0	35.0	425.0	850.0	2,100	25,990	575	690	26.7
Spain	26-cm.	10.24	L.	Krupp	27.2	358.3	32.0	180.8	608.4	1.725	12,550	462	390	20.2
England	10″	10.0	N.	Government.	29	342.4	32.0	250.0	500.0	2,100	15,290	527	487	22.5
United States..	10″	10.0	N.	Government	24.1	329.0	31.0	250.0	500.0	2,000	13,870	576	441	21.5

NOTE.—N, naval; L, land.

RAPID-FIRE GUNS.

About the close of the year 1881 England advertised for designs of a gun that should fulfill the following requirements, viz.:

The weight of the gun and mount not to exceed 10 hundredweight; the projectile to weigh 6 pounds and have a muzzle velocity of not less than 1,800 foot-seconds; the projectile and powder charge to be made up in one cartridge; the service of the gun to require not more than three men; under the above conditions the gun to be capable of firing at least twelve aimed shots per minute.

France, about the same time, invited designs for a 3-pounder, to fulfill, relatively, the same conditions.

These two advertisements are the origin of what are now known as the Hotchkiss and the Nordenfelt rapid-fire guns, types that to-day form part of the armament of nearly every great naval power, Germany being the sole exception of any importance.

These guns were intended chiefly as a defense against torpedo-boats, for which purpose the 6-pounder was considered to possess ample power, and for a long time it remained the heaviest calibre in use. But quite recently it has been sought to utilize the advantages of the rapid-fire system in the construction of guns capable of attacking armored structures, and up to a certain point the efforts in this direction have been attended with great success. Hotchkiss has produced a 33-pounder and has in preparation a design for a 55-pounder, both being fitted with his already well-tried breech-closing device, while Armstrong has successfully applied his newly invented mechanism to 4.72-, 5.5-, and even 6-inch guns.

In the course of some competitive trials (made in the presence of British Admiralty inspectors) between the 4.72-inch gun and a service 5-inch breech-loader, the former fired ten consecutive shots in forty-eight seconds, while the same number from the service gun required five minutes seven seconds.

Evidently the great advantage of the rapid-fire system must be due solely to details of breech mechanism and ammunition; and, this being the case, the United States is in condition to add at once to its naval armament guns of a type that will compare favorably with any other in existence. The country has a plant capable of supplying metallic-cased ammunition to guns of any calibre to which it is possible successfully to apply this system of loading, and the Navy Department has secured the right to the Driggs-Schroeder breech mechanism, a mechanism obviously more logical and practical than the Armstrong, and possessing a marked advantage over any other in point of weight, while it offers at least equal guaranties of safety.

GUN-CARRIAGES.

The improvement that has been made in gun-carriages, and especially in the devices for checking recoil, cannot be better illustrated than by describing a few typical mounts of approved pattern.

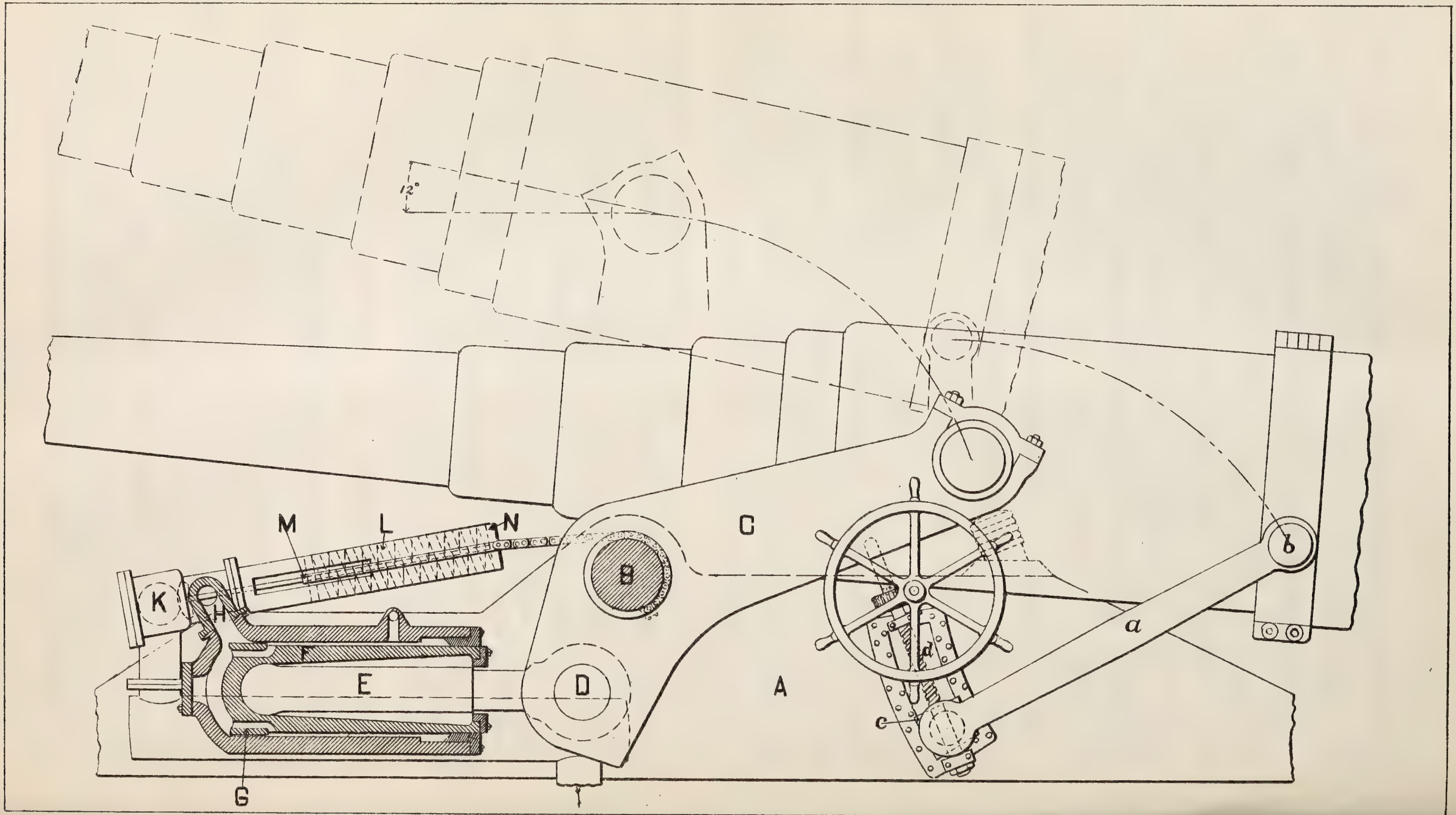
DISAPPEARING CARRIAGE FOR NAVAL SERVICE.

Plate 5 shows an outline of the disappearing mount designed for the 12-inch 50-ton guns of the Russian ships *Catherine II*, *Sinope*, and *Tchesma*.

The guns are mounted in pairs. The platform revolves on live rollers through the agency of a vertical shaft and a pinion which gears into a rack on the platform, the shaft being revolved by a steam-engine below decks. The carriage brackets A are bolted to the platform; each pair carries a rocking-shaft B, on which is secured a pair of levers C, the upper ends of which are formed into trunnion bearings, while the lower ones have threaded through them a spindle D. On this spindle is coupled a pair of connecting rods E, the forward ends of which are spherical and abut against the bottom of the hollow steel plungers F, which work in the recoil cylinders. The pistons G are of a diameter only slightly greater than the plungers and are fitted with ports to keep up a free circulation of water between the forward ends of the cylinders and the annular spaces surrounding the plungers. The upper end of each cylinder is provided with an escape pipe H, which joins a recoil valve chest K, common to both pairs of cylinders. The recoil valve is an ordinary conical valve fitted with a strong steel spindle, which passes through a balancing cylinder and stuffing-box towards the main rocking-shaft and is secured to the disc N. As the effect of the recoil on the plungers increases as the gun descends, the load on the recoil valve must be made adjustable; this is done by means of disc springs L on the valve spindle, which abut on a cross-head M, connected by a pair of tension-rods with a cam movement on the rocking-shaft, the movement being so adjusted that the tension on the springs is least when the gun is in the firing, and most when in the loading position.

For raising the gun water under about 970 pounds pressure to the square inch is admitted to the rear ends of the cylinders, whence it passes through the ports to the forward ends and drives the pistons before it until they gradually shut off the water and the gun gently comes to rest. The water is supplied from an air accumulator of a capacity sufficient to raise both guns once without assistance from the pumps. The water from the recoil valves is discharged into a pipe common to both pairs of cylinders, whence it passes through the centre pivot back into the tank from which it was originally pumped into the accumulator under pressure.

PLATE 5.
Disappearing Carriage for Naval Service.



The elevation or depression of the gun is effected by means of a bar *a*, attached at its upper end to a small trunnion *b* at the breech of the gun, and at its lower end to a block *c*, which is caused to move in the curved slot *d* by a hand-wheel and gearing. The slot is the arc of a circle constructed with the elevating bar *a* as a radius and the point *b*, which is the position of the trunnion when the gun is down for loading, as a centre; so that, whatever the elevation when fired, the gun always recoils to the same position, and can be laid for range (as well as trained) while loading. The ammunition is hoisted by means of an inclined endless chain actuated by a small steam-engine.

PNEUMATIC DISAPPEARING GUN-CARRIAGE FOR LAND SERVICE.

The carriage shown in Plate 6 is one designed by the Pneumatic Gun-Carriage and Power Company for the Army 10-inch breech-loading rifle, and will serve to illustrate the general principles governing the construction and emplacement of land disappearing mounts. It will be seen that when in the position most favorable to the enemy's fire the gun is entirely protected against any projectile arriving with an angle of fall of 5 degrees or less, and it is proposed to furnish further protection against rapid firing and machine-gun fire by a shield. The slide is pivoted well in front in order that it may be traversed to a position parallel with, and close to, the parapet and bomb-proof, for greater security while loading.

The trunnions of the gun are mounted on the upper ends of two elevating levers A, the lower ends of which are pivoted to the slide at B. The gun is raised to the firing position by means of compressed air acting upon a movable piston and rod D, which work in the cylinder C. The piston-rod is connected to the elevating levers by means of a cross-head, upon each end of which are arranged friction-rollers working in elongated bearings in the levers, whereby the arc motion of the latter permits a rectilinear motion of the cross-head. E are saddles, which fit over flanges on the slide, to give direction to the cross-head and additional support to the gun when in the firing position.

The compressed air, at a tension sufficient to raise the gun to battery, is supplied to the cylinder from the receiver of an air-compressor through the pivot G and pipe G′. Upon recoil this air is still further compressed and forms a cushion of a pressure sufficient to take up the recoil. The compressed air gradually escapes through a non-return valve which closes at the end of the recoil. After loading, the confined air is readmitted to the under side of the piston through a by-pass valve operated by the hand-wheel H, and the gun is returned to the firing position. Buffers, I, are provided to support the gun when down.

The operations of training and elevating or depressing are performed by a small reversible air-engine K, in a protected position under the gun. The engine is provided with a follow-up stop-motion valve, which is controlled by the hand-wheel L. The air is supplied through the pivot G and pipe R. The slide is traversed by means of beveled gears engaging in the rack M, and worm-gears connecting with a cross-shaft, which gears to the crank-shaft of the engine. This last gearing can be disconnected by the throwing out of a clutch worked by the lever N, and the reversing can then be done by levers shipped on projections of the cross-shaft through the cheeks of the slide. The elevation or depression of the gun is effected by means of the rod O^1, rack and pinion P, worm P^1, and beveled wheels P^2, and it may be effected by either hand or engine power. S is a pneumatic rammer. The recoil cylinder can be charged by a large differential manual air-pump, thus dispensing with the use of steam in drill practice.

VAVASSEUR CENTRE-PIVOT CARRIAGE.

Plate 7 is a section of the Vavasseur centre-pivot carriage designed for the Armstrong rapid-firing guns.

The base plate *a* is nearly flat and is provided with a centre-pivot *b*, around which is a grooved track for the hardened steel balls *c*, which, with conical rollers *d*, support the carriage. This arrangement reduces the friction to a minimum and enables one man to train the gun by simply pressing against the shoulder-rest; the gun is retained in any desired position by means of a friction brake, operated by a hand-wheel near the breech of the gun.

The elevating gear consists of a transverse horizontal shaft provided with a hand-wheel and connected by beveled gears with a vertical shaft, on which is a screw-thread working into a nut on an arm projecting from the left side of the control cylinder.

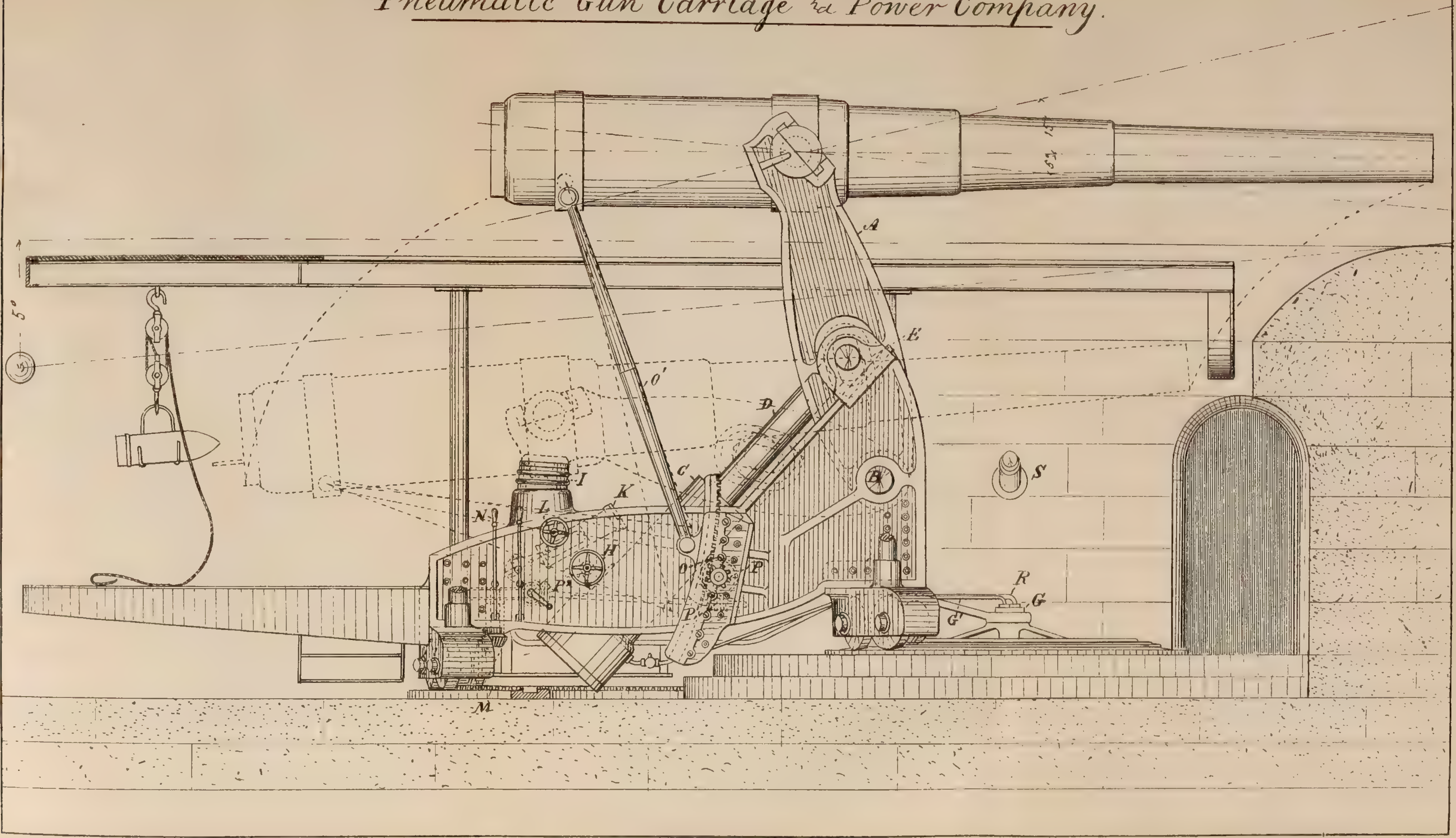
The gun is without trunnions and is free to slide to and fro in the rings A and A^1. At its rear end is a lug B, to which the rod D of the piston d, and the two rods E are attached, the latter passing forward on each side of the cylinder C to the cross-head F. Against this cross-head abuts the disc G, pressed forward by the spring H, the rear end of the spring taking against a flange on the hollow core-piece I. A stem K, passing loosely through the cross-head F and disc G, screws into the head of the core-piece I and gives the spring a suitable initial compression. L is a fixed plug in the cylinder, which, when the gun is out, enters a corresponding cavity in the piston-rod; it serves when the gun moves forward to bring it to rest gradually, the liquid in the rod being able to escape past the plug only very slowly. The liquid is forced into the cavity during recoil through a hole in the piston-rod.

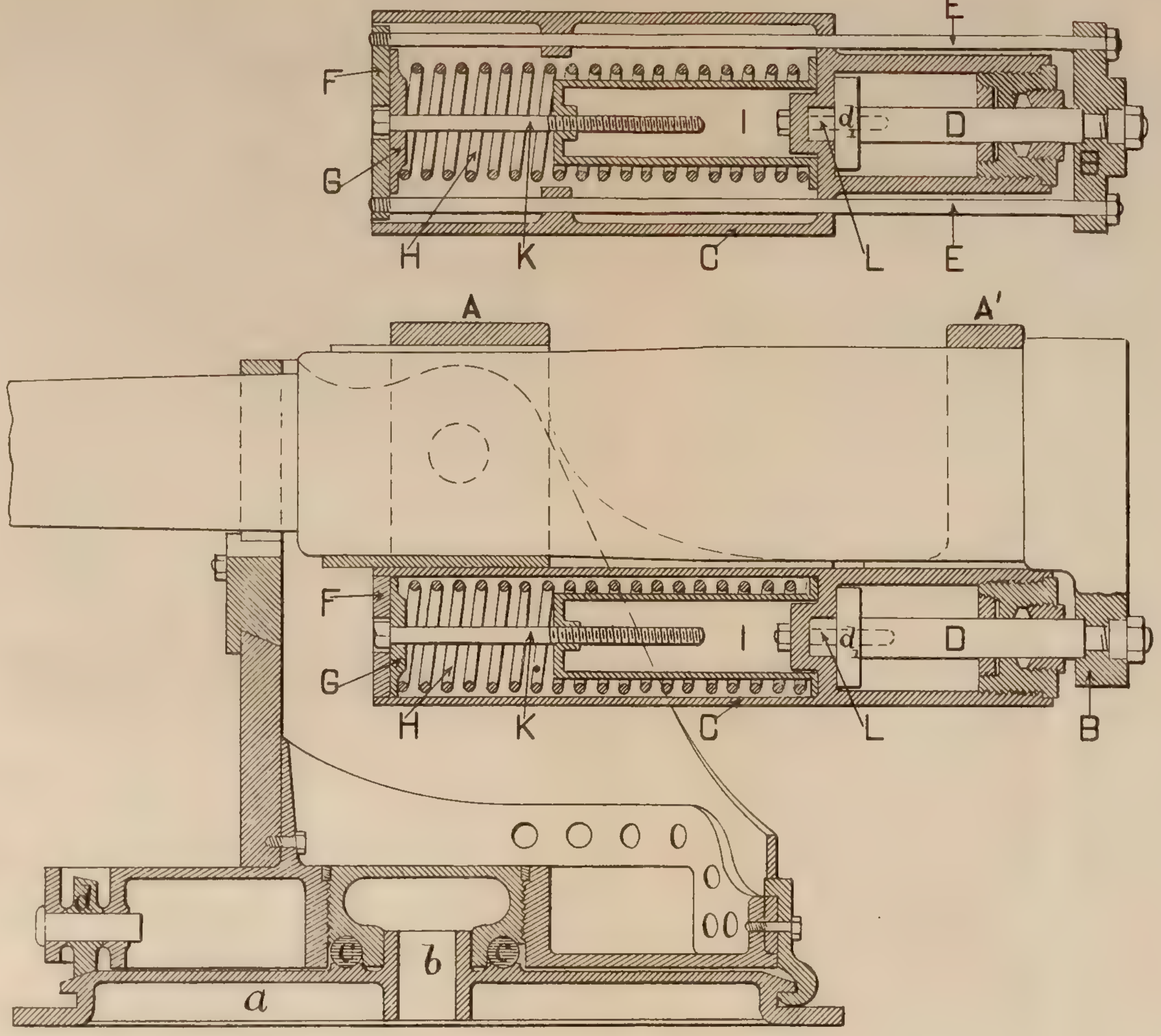
The general working of the Vavasseur piston will be understood by reference to the accompanying cut.

The pistons A are made solid on the rods B, are a loose fit in the cylinder, and are provided with two openings or ports, *a*, of about the shape shown in the transverse sections 1 and 2. On the pistons, and free to revolve about them, are ring-valves C, with ports *c* and lugs c, the

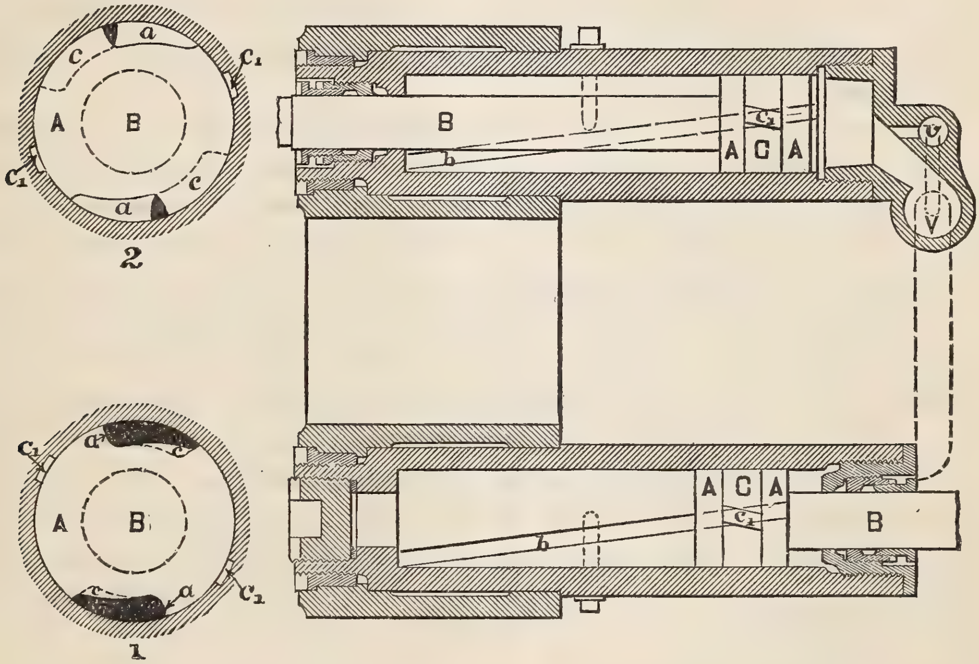
Pneumatic Disappearing Carriage. For 10'' B.L.R.

Pneumatic Gun Carriage and Power Company.




E
F
G
I
d1
D
B
H
K
C
L
E
A
A′
F
G
I
d1
D
H
K
C
L
B
d
c
b
c
a

latter working in rifle-grooves *b* in the cylinder. When the gun is out to battery the valve-ports are in line, or nearly in line, with the ports in the piston, as at 1; as the gun recoils the lugs follow the rifling, causing the valves to rotate, until finally the ports in the piston are closed, or nearly so, as at 2. The valves may be set in any position relative to the piston, and the amount of recoil thereby increased or diminished at will.



In the arrangement here shown, which is that of the 6-inch centre-pivot mounts of H. M. S. *Canada* and *Cordelia*, the recoil of the gun causes a certain volume of fluid to pass from the left to the right hand cylinder through a spring-loaded valve, V, which drops at the end of the recoil; on running out, the flow of the liquid tends to keep the valve closed, so that it can pass only through the by-pass valve *v*. By keeping *v* closed the carriage will remain in at the end of the recoil; or, by opening it to a greater or less extent, the speed of running out can be moderated as desired.

In a later Vavasseur design both piston-rods are secured to the forward ends of the slides, and the ports in the two pistons are made of different dimensions; during recoil, then, a higher pressure will be generated in front of the piston with the smaller ports, and the fluid will flow from that cylinder to the other one. The valves in the communicating pipe are arranged as just described.

UNITED STATES 6-INCH RAPID-FIRING CARRIAGE.

Plate 8 represents a preliminary design for a 6-inch rapid-firing mount, prepared under direction of the Bureau of Ordnance by Lieut. F. F. Fletcher, U. S. Navy.

A is the base plate, provided with a hollow central pivot, B, surrounded by ball rollers *r*, which, with the deck circle C, support the carriage, held down by clips *k*. The gun is mounted in a rocking slide D, in which the gun is free to move to and fro, and which is pivoted to the carriage by the trunnions *t*.

The elevation is effected by means of an electric motor M, located on the forward part of the transom. The motor shaft *a* is vertical, and is provided at a' with an endless screw working in a gear wheel, b', on the shaft *b*, whose motion is transmitted to the toothed arc *d*, on an arm of the rocking slide, through the media of the endless screw b^2 and the gear-wheels c' c^2 on the shaft *c*.

The training gear is set in motion by a second motor M′, working a horizontal shaft *e*, whose motion is transferred to the shaft *f* by means of the endless screw e' and gear-wheel f', and thence to the carriage by an endless screw which works in the gear-wheel *g* on the fixed pivot.

The recoil cylinder E is securely attached to the gun by the bands F F′, and consequently shares its recoil. The forward end of the piston-rod G is secured to the rocking slide, and the rear end to the head of the cylinder H. The forward end of the spiral spring I takes against the rear end of the cylinder and is compressed by the recoil, and the energy thus stored up afterwards returns the gun to battery. The fluid passes from the front to the rear side of the piston during recoil, and in the reverse direction during the counter recoil, through two diametrically opposite grooves in the cylinder. (A development of the groove is shown in Fig. X.)

Both elevation and train are controlled, and the gun is fired, by a man seated on the gun carriage at K, the electric circuit being made or broken by movements of the directing bar R and the trigger T.

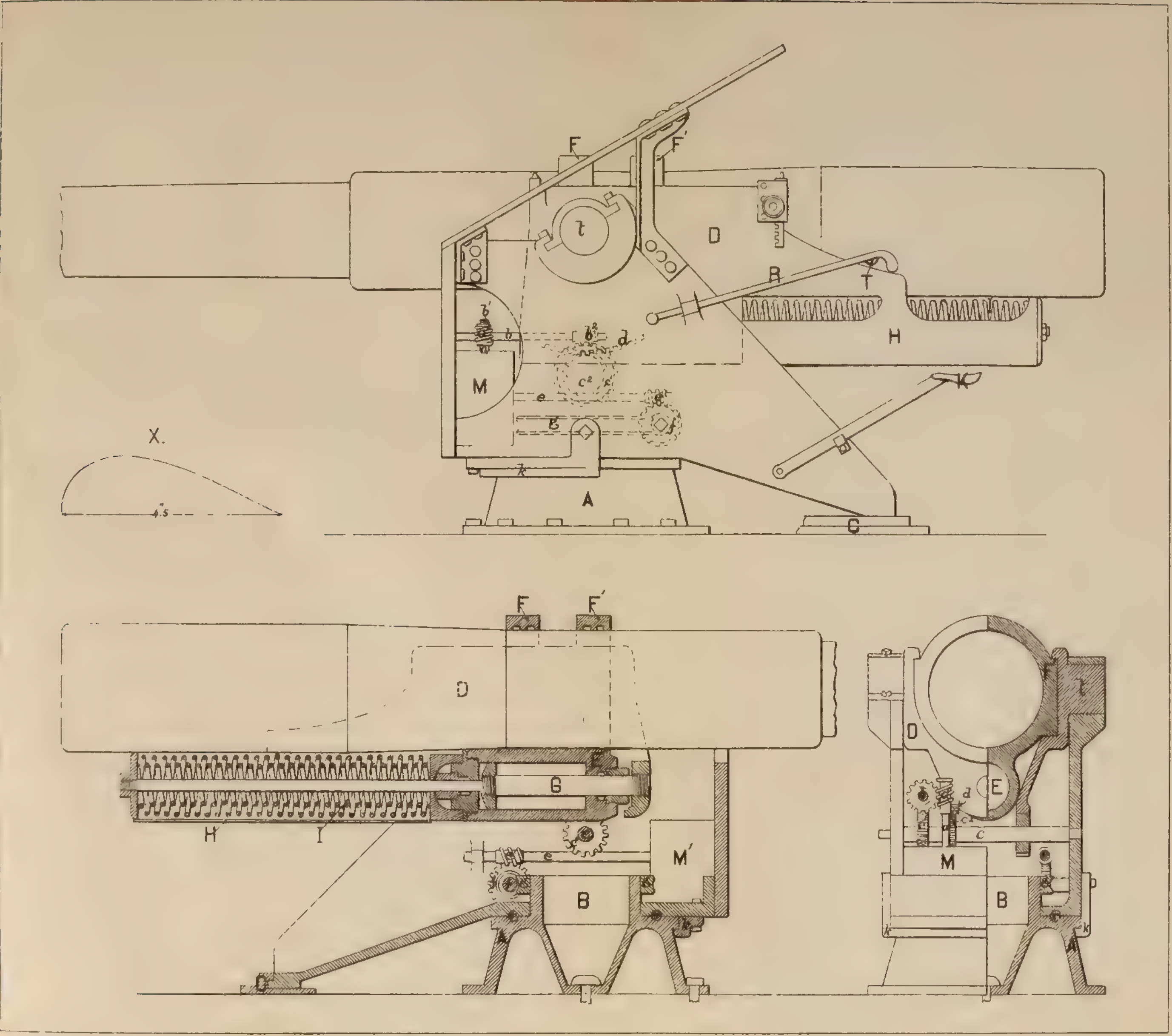
POWDERS.

Prismatic powder, the suggestion of an American, was first experimented with in Russia, although it is to Germany that it owes its complete development.

In the first prismatic powders the manufacturing processes were the same as those of the old powders until after granulation; the granulated powder was then simply pressed in molds and dried. They were made to burn with different degrees of rapidity by varying the densities, the size of grain, and the number and size of channels by which the flame could communicate with the portion of the charge farthest removed from the point of ignition. They gave less pressure for the same velocity than the old powders and had the further advantage of making up into more regular shapes, in consequence of which they yielded more uniform pressures and more accurate targets.

U. S. 6-inch R. F. Mount.

PLATE 8.



The black prismatic powders answered admirably for the guns for which they were intended; that is, for guns in which the length of travel of the projectile did not exceed 18 calibres, but with guns of 30 and 35 calibres length still slower powders became necessary. The German manufacturers met this new demand upon their ingenuity and resources with the brown or cocoa powder. The peculiarity of this powder, and that which constitutes its advantage over all others made up to the time of its introduction, is that it burns slowly at first, but by the time the resistance of the rotating band has been overcome, and the projectile has been fairly started, it is burning very rapidly; the maximum pressure is thus greatly reduced, and work is done on the projectile until it leaves the bore.

The following tabular comparison of some results obtained, in 1882, with varying charges of Rottweil-Hamburg brown (C/82) and black (C/75) prismatic powders, illustrates the immense superiority of the former. It is especially stated in the report that C/75 powder was of good quality and had been tested repeatedly. The firing was from a Krupp 21 cm. gun of 30 calibres length.

Powder.		Projectile.	Muzzle velocity.	Pressure—crusher gauge.	Muzzle energy.	
Description.	Charge.				Total.	Per ton of pressure.
	Pounds.	*Pounds.*	*Ft. secs.*	*Tons per square inch.*	*Foot-tons.*	*Foot-tons.*
C/82	86. 0	308. 3	1, 578	12. 9	5, 323	413
C/75	86. 0		1, 607	18. 5	5, 521	298
C/82	92. 6	308. 3	1, 637	14. 1	5, 729	406
C/75	88. 2		1, 630	19. 1	5, 680	297
C/82	99. 2	308. 3	1, 702	15. 6	6, 190	397
C/75	88. 2		1, 660	19. 5	5, 891	302

NOTE.—The United States Navy gun most appropriate for purposes of comparison with the Krupp 21 cm. is the 8-inch B. L. R. mark I, which has a total length of about 32 calibres. It will be seen by reference to the table on page 146 that this gun, using 125 pounds of Dupont powder, gives the projectile of 250 pounds weight a velocity of 2,000 foot-seconds; the chamber pressure is 15 tons. The total energy is 6,934 foot-tons, or 462 tons per ton of pressure.

Another valuable property claimed for the new powder, and which it is stated was fully confirmed at these trials, is that it gives rise to comparatively little smoke.

The brown differs from the black powder chiefly in the proportion of its ingredients and in the chemcial composition of the charcoal;* like

---

* Analyses of samples of Rottweil-Hamburg powders, made at the Russian School of Pyrotechny in 1884, gave the following proportions:

	A powder.	B powder.
Saltpetre	78	76
Sulphur	2	4
Charcoal	20	20
	100	100

the black powder it is made to burn with different degrees of rapidity by modification of the mechanical treatment.

The slow-burning powder forms the most conclusive proof yet adduced of the absolute necessity of the breech-loading type of gun: it undoubtedly gives results superior to those of any other powder, and in order that it may burn efficiently, the projectile must be retained in its initial position until a considerable pressure has developed; with the B. L. projectile this desideratum is obtained by the use of a rotating band of diameter considerably greater than the calibre, which furnishes the requisite resistance; with the M. L. projectile such a device is mainfestly impossible. Its use has led to decided modifications in ordnance designs: since the maximum pressure at the breech is less than was formerly the case, metal can be spared at that point to add to the length of the bore, and as the pressures are well sustained throughout the entire length of travel of the projectile, the thickness of the metal along the chase has been correspondingly increased. On the whole, however, there has been a vast saving of weight when measured by the standard of the foot-ton of energy.

Since the advent of the prismatic brown powder efforts have been making constantly to obtain the same results in a greater degree, *i. e.*, to obtain an explosive which shall be safe, comparatively smokeless, and give increased velocities without corresponding increase of maximum pressure.

The United Rhenish Westphalia Powder Company has lately produced a powder known as P. P. C/86, of which the following particulars are gathered from Krupp's report, No. 73: With the 10.5 cm. Krupp gun an 8.6-pound charge of P. P. C/86 gives to the regulation projectile of 39.7 pounds weight a velocity of 1,729 foot-seconds, the pressure being only 12.8 tons; with 10.4 pounds of P. P. C/82 the velocity is 1,637 foot-seconds, and the pressure 13.6 tons. When fired from the 15 cm. $^{L}/_{35}$ gun, a charge of 34.2 pounds of the new powder imparts to the 112.4-pound projectile a velocity of 1,945 foot-seconds, with only 15.4 tons pressure, whereas a charge of 51.8 pounds of the old powder gives rise to 16.7 tons pressure (1.3 tons greater), with about the same velocity (3 feet less).

This is doubtless the same powder as that used in the round made last year with the Armstrong 4.72-inch rapid-firing gun, in which, with a 12-pound charge and 36-pound projectile, a velocity of 2,380 foot-seconds was recorded; with a 45-pound projectile the velocity was 2,073 foot-seconds, the pressure being under 16 tons.

Analyses of the charcoal of these powders gave the following:

Carbon	58.3
Hydrogen	5.6
Oxygen	33.2
Nitrogen	1.8
Ash	1.1
	100.0

These are probably the best results obtained with German powders up to the present.

It has been hinted from time to time that certain difficulties are to be overcome before this new powder can be pronounced thoroughly serviceable, and it is probable that one of the difficulties referred to is its hygroscopic properties. A statement has been made by an English army officer, and quoted in a prominent English journal, to the effect that if exposed to the atmosphere for any length of time the new powder becomes absolutely useless, changing to a mass of mud or slime.

France has lately produced a powder of which it is said that in a round from a 16 cm. gun, the projectile weighing about 100 pounds, and the charge being little more than half the service weight, a velocity of over 2,600 foot-seconds was obtained, with no increase of maximum pressure. The heaviest charge of the most powerful French gun of the calibre named actually in service is 46.3 pounds of Sévran-Livry prismatic brown powder, which gives to the battering shell of 99.2 pounds weight a velocity of 1,968 foot-seconds, with 16.5 tons pressure. The projectiles being the same, the energies corresponding to these velocities are to each other as 7 is to 4.

If the new powder is safe and possesses good keeping qualities it will unquestionably place France at the head of the world in point of power and effectiveness of its artillery. It simply makes a 16 cm. gun equal to the best 19 cm. possessed by any other nation—a 6-inch equal to the best 7-inch.

PROJECTILES.

Twelve years ago the chilled cast-iron projectile was considered to be all that could be desired for work upon the wrought-iron armor of that period, and, in fact, an extensive series of experiments made in England in 1876 tended to prove that against this type of armor the chilled iron was fully equal to the steel shell in normal, while it was slightly superior in oblique fire. The experiments alluded to also included tests of chilled-iron projectiles against steel plates, and the results of these were such as to lead to the emphatic declaration on the part of the committee in charge that "steel shell are absolutely necessary for the attack of steel-faced armor," a verdict which has been fully sustained by subsequent trials.

The present steel armor-piercing projectile has been developed chiefly in France and by Krupp in Germany. In the first-named country some half dozen establishments are successfully engaged in its manufacture, each practicing some special mode of treatment, or using some particular chemical combination, which is either kept secret or protected by letters patent. At Terre Noire, for example, the steel is oil hardened but not forged, and the quality of the steel varies in different projectiles, being softest in the largest calibre; but the degree of hardening varies also, so that the final product possesses nearly the same degree of hardness in all cases. St. Chamond projectiles are generally made of crucible steel, forged and oil hardened; but here the quality of the steel is the same for all calibres, and the hardening process differs. That for a 34 cm. shell is described as follows: The projectile is brought to a cherry-red heat throughout, plunged in oil and kept immersed until cold; it is then brought again to a cherry-red and dipped in cold water as far as the front band, where it is kept eight or ten minutes; finally it is wholly immersed in oil until cold. The Firminy and the Holtzer processes are secrets.

Krupp projectiles are of crucible steel, and the final process is oil hardening; it is said that a file will not bite anywhere on the surface. Some fragments of a Krupp shell fired against a Gruson shield in 1886 were tested in England and found to contain about 0.88 per cent. of carbon.

The following table will serve to show about what may be expected of the steel armor-piercing projectile, and also to indicate its general behavior when fired against the modern armor-plate. The fire in all cases is normal.

Date.	Projectile.	Plate.	Energy per inch of shot's circumference.	Calculated perforation of unbacked wrought iron.	Remarks.
			Foot tons.	*Inches.*	
1888	St. Chamond 13.5-inch; weight, 1,250 pounds.	Brown compound, 6′ by 6′ by 18″. 6″ wrought iron and 12′ oak backing.	825	29.2	Shell penetrated to the backing and broke up into fragments.
	Firminy 13.5-inch; weight, 1,250 pounds.	Cammell compound plate of same dimensions and backing.	825	29.2	Penetration not quite so deep as in preceding, and projectile broken up more completely.
1887	Holtzer 12-inch; weight, 714 pounds.	Brown compound, 16″ thick.	470	22.1	Complete perforation of plate and 10′ backing; projectile so little deformed that it could have been used again.
1887	Firminy 12-inch; weight, 718 pounds.	Cammell compound, 5′ by 5′ by 16″. 12′ backing.	452	21.7	Complete perforation; shell buried itself to a depth of 8 feet in the backing.
	Firminy 12-inch; weight, 720 pounds.	Brown compound, 16″ thick. 12′ backing.	452	21.7	Shell softer than the preceding; failed to get through and broke up.
1888	Krupp 8.3-inch; weight, 304 pounds.	Cammell compound, 11′ by 9′ by 15″.5.	265	16.7	Two rounds; complete perforation; projectiles recovered 43 and 733 yards in rear of target.
1886	Holtzer, 5.9-inch; weight, 80 pounds.	Le Creusot steel, 18″.9 thick.	105	10.6	Three rounds with each. Holtzer—mean penetration 9″.5; shell rebounded entire; no appreciable deformation.
	Krupp 5.9-inch; weight, 80 pounds.				Krupp—mean penetration 8″.8; shell rebounded entire; slight upsetting.

The use of steel has lately been extended to the manufacture of common and shrapnel shell also; the thickness of the shell walls is thereby greatly reduced, while retaining all the strength of the cast-iron projectile, so that the interior capacity for bursting charge or bullets, and consequently the efficiency of the shell, has been correspondingly increased. These projectiles are generally made of cast-steel, but in England the difficulty of procuring sound small castings led to the introduction of forged steel for the smaller calibres, and the superiority of these over the cast-steel ones was so marked that they are now made for all calibres up to 12-inch. The annexed table will illustrate:

	Weight of bursting charges for English steel and cast-iron common shells.			Number and weight of balls in English steel and cast-iron shrapnel shell.			
	Cast-iron.	Cast-steel.	Forged-steel.	Cast-iron.		Forged-steel.	
	Pounds.	*Pounds.*	*Pounds.*	*No.*	*Weight.*	*No.*	*Weight.*
12-inch; weight, 714 pounds.	31.2	95.0	....	340	4 oz.	1,120	4 oz.
9.2-inch; weight, 380 pounds.	18.0	....	33.0	420	2 oz.	900	2 oz.
8-inch; weight, 210 pounds.	13.6	....	29.0	260	2 oz.	528	2 oz.
6-inch; weight, 100 pounds.	7.2	9.3	....	259	14 to the lb..	700	16 to the lb.
5-inch; weight, 50 pounds..	3.3	....	8.0	Obsolete.		236	14 to the lb.
4-inch; weight, 25 pounds..	1.4	....	3.4	40 105	39 to the lb.. 20 to the lb..	238	22½ to the lb.

The problem of throwing projectiles charged with some substance more powerful than gunpowder is engaging the attention of artillerists the world over; but the dangers attending the transportation and use of the explosives best suited to the purpose have so far acted as powerful deterrents to their general adoption. It is true that two of the most dangerous compounds known, dynamite and nitro-glycerine, have been fired from service guns without accident, but either they have been used in such small quantities or have been subjected to such modifying treatment that it is a question if the results obtained have exceeded those safely within reach by the use of gunpowder.

The most important results recorded of dynamite shell fired from powder guns are those obtained within the past three years under the direction of Mr. Graydon. It is now well known that the method by which Mr. Graydon seeks to overcome the disposition of the charge to explode prematurely is, briefly, by dividing the dynamite into a number of small pellets, each inclosed in an envelope of impermeable material; by dividing the interior of the shell into compartments by means of transverse partitions; and by lining the shell with some non-conductor of heat, such as asbestos.

The most complete series of experiments up to date is that of December, 1887, of which a full report will be found in General Information Series No. VII, p. 376. The firing on this occasion was from a

7-inch M. L. R. The projectiles were steel shell of service pattern, but provided with a large base opening for convenience of lining and loading; the total weight, when charged with 2.3 pounds of dynamite No. 2, was about 122 pounds. The powder charge was 23 pounds. Mr. Graydon fully demonstrated his ability to handle and fire shell charged by his method with rather less than 2.5 pounds of No. 2 dynamite; but it is doubtful if an equal amount of damage would not have been done the target (a section of wrought-iron turret composed of two 7-inch plates) by the same number of empty shell.

The experiments with the Smolianinoff projectile, made about the same time, were even less conclusive, although in this case the weakness of the cast-iron shell used precluded any possibility of penetration, without which, it was claimed, no really excellent results could be looked for. Mr. Smolianinoff's explosive consists of 80 parts of nitro-glycerine combined with 20 parts of a certain fluid of which the composition is a secret. It is claimed for the mixture that it is insensible to shock, either in the gun or against a target, and that a detonating fuse is required to explode it.* On the occasion referred to the charge weighed 4.6 pounds, the weight of the empty shell being about 90 pounds.

Common report credits Mr. Snyder with having destroyed a target composed of twelve 1-inch steel plates by means of a 6-inch shell charged with 10 pounds of his explosive, of which 94 per cent. is nitro-glycerine. No official reports concerning the manner of putting the target together have ever been made public, and no new experiments have taken place within the past year. Mr. Snyder's safety device lies not in the treatment of the explosive, but in the construction of the projectile. This is in two parts: the forward one is the shell proper, which carries the bursting charge; the rear part is a cylinder, which laps over the base of the shell and contains a piece of india rubber fluted outside and having a number of longitudinal perforations in the interior. When the gun is fired the india rubber, combined with the air in the holes, acts as a cushion and prevents premature explosion.

Two other explosives, more than any of the foregoing, have recently attracted close attention; these are melinite and gun-cotton. The French have succeeded in throwing melinite shell from high-power guns with velocities as high as 2,000 foot-seconds, and, while the amount of the explosive is not stated in this particular case, it is known that charges of 70 pounds have been repeatedly fired from the 22^{cm} howitzer, with velocities approaching 1,300 foot-seconds. It has been evident for some time that in their employment of this explosive the French had passed from the experimental stage to one of the utmost confidence; but they had hardly arrived at this point when it was reported that, owing to the difficulty of obtaining the materials of which melinite is composed, its use is to be abandoned. It should be added that this report has never received official confirmation. Should the main fact of the statement concerning the explosive prove true it will still be open to doubt that the reason given for its abandonment is the real one.

---

* In one round, at least, these claims have not been substantiated. See Notes on High Explosive Projectiles, p. 418.

The explosive force of the French melinite is stated on good authority to be about three times that of gunpowder.

Under the name of lyddite the English have been experimenting with what is probably only one of the earlier forms of melinite, but thus far they seem not to have succeeded in getting it under control. It is certain that in the *Resistance* experiments much more work was done by gunpowder shell than by those filled with lyddite.

The latest-received reports of useful results obtained with gun-cotton shell are given at length in the notes on high-explosive projectiles (p. 420). It appears there that Mr. von Förster, Director of the Walsrode gun-cotton factory, has devised a fuse which insures detonation of a wet gun-cotton charge on impact of the shell and will not cause the charge to detonate at any other time; but it should be observed that in no case does the initial velocity exceed 1,560 foot-seconds, and the experiments themselves show that the amount of fulminate used in the fuse is such as to render its premature detonation not improbable with any increase of velocity, and the quantity of dry cotton priming is sufficient of itself to rupture an iron shell of armor-piercing pattern.

So far as known the most powerful guns provided with gun-cotton shell as a part of the regulation outfit are the Italian 28- and 24-cm. howitzers, in neither of which is the velocity much above 1,000 foot-seconds.

This velocity does not greatly exceed that of the pneumatic dynamite gun.

It has been the fashion with many in England to cry down this weapon as useless, just as it has been too much the habit in the United States to laud it as one destined to supersede all other types of artillery. It should be understood that this exaggerated claim has not been advanced either by Captain Zalinski or by military men in general; it *is* claimed for the gun, however, that it forms a powerful auxiliary to existing types of weapons, both for attack and defense.

The reports of its performances have been given in detail in past numbers of this series and are continued in the present publication, and a study of these can not fail to suggest how admirably the dynamite gun supplies the want expressed in the following quotation from Commander Goodrich's report on British Naval and Military Operations in Egypt. Commander Goodrich says:

> "If Admiral Seymour had possessed a vessel carrying both heavy modern high-powered guns and large howitzers, or other shell guns capable of great elevation, and thus somewhat similar to the mortar in application, she would have been of immense value."

Had Admiral Seymour's fleet included a *Vesuvius*, that vessel could have placed herself behind any one of the huge armor-clads of the attacking squadron, and from that position could easily have landed within the shore-works, at an angle of fall of about 25 degrees, projectiles filled with the enormous charge of 500 pounds of dynamite The effect can be imagined.

Conversely, had the shore-works possessed one or more dynamite guns, the attacking fleet probably would not have calmly delivered its fire from an anchored position within a 1,600-yard range.

V.

NAVAL GUNNERY.

By Lieutenant J. F. Meigs, U. S. Navy.

Charles Morris, who served with distinction in the *Constitution* and elsewhere during the war of 1812, says of that war in his autobiography:

> But the great source of our success was undoubtedly the superior management and direction of our guns; and that the English and other governments were satisfied of this is sufficiently evident by the careful attention they have since continued to give to this branch of the naval service.

By superior management and direction of guns Morris does not mean superior marksmanship alone. He undoubtedly does mean that the men who pointed the guns were good shots, and that the guns' crews were well trained in handling the guns quickly and surely; but he means that the officers also performed their part with reference to the guns well. He meant that what is now called gun control was good, and that the gun tactics was good.

So many naval actions have been won by good gunnery—not by good marksmanship alone, but by good gunnery—that no amount of attention we may pay to it can be lost. The *Kearsarge* defeated the *Alabama* solely because her gunnery was better—she could hit oftenest in a given time. The range at which this action was fought (from 700 to 1,100 yards) was such as to bring in, in all its bearings, the matter of control. Not only must the speed of serving the guns be well regulated, but the sight-bars must be properly placed. In the absence of knowledge on the subject we have just as good reason to ascribe the *Kearsarge's* victory to good control as to good marksmanship. It was, indeed, by common report at the time largely attributed to the effective way the battery was worked by the first lieutenant. The term "working the battery" means the same as control. The *Weehawken* and *Atlanta* contest, again, was decided purely by good gunnery. The tactics in the cases of the two battles were wholly different, and different matters of control came in; but these two battles, among the most celebrated of modern sea duels, were won entirely by good gunnery.

Considering the large amount of money spent in navies at target practice with large guns, we know very little of the quality of their shooting when afloat. The principal reason for this is the want of a proper target. We know all about how the great rifle teams shoot. Their targets may differ slightly, but we have them fully described. The recording of naval gun practice is, however, notoriously imperfect. When the pneumatic-dynamite gun was tried for accuracy there was no question as to how its accuracy should be proved. The points of fall of the projectiles were marked by cross-bearings in the horizontal plane. In firing over water at proof grounds, no one thinks of determining the points of fall otherwise than by cross-bearings in the horizontal plane. Why is not naval gun practice habitually observed in the same way? This method, under ordinary conditions and with the observers in boats in a seaway, will give the points of fall truly to within about 10 yards horizontally, which is a limit of error quite narrow enough to admit of our correcting the practice of guns in its most important particular.

There is at present no way of obtaining the record of the performance of guns at sea except by observing the points of fall by two horizontal angles with respect to the target. It will at times be difficult to do this; but it must be admitted that target practice which fails to show a true record of what has been done falls much lower in value than that so carried out that we know the whole history of it.

In ordinary practice on board ship, particularly when several guns are firing rapidly at will, the method of noting the points of fall by two horizontal angles will not give the side errors in a satisfactory manner. We determine the position of the shot sideways with the same precision that we determine its position in range; and the horizontal angles will, under ordinary circumstances, give the points of fall within 10 yards. Now the proper side error of a gun, even in the hands of a comparatively unskillful person, is considerably less than 10 yards, while its range error is considerably greater than 10 yards. If we consider the dispersion of the points of impact on a vertical target passing through the actual target this will be even more striking. On this latter target we can not depend upon the sideways position of our marks to within 10 yards, but their vertical positions are much more nicely known. Thus, by observing by cross-bearings the points of fall of a 6-inch B. L. R., when firing at a target 1,000 yards distant, we shall determine the dispersion on a vertical target to within about 8 inches, but the sideways dispersion can not be relied upon to within less than 10 yards. The method will not, then, enable us to correct the side errors. It amply enables us to correct in a vertical sense, but is incapable of correcting sideways. The only thing which offsets this want is the fact that the targets usually presented in naval warfare are so broad that it requires little skill to hit them sideways. But it must be acknowledged as a great fault of the vertical target that the side position on it is almost valueless.

The form of sights has undoubtedly some influence upon practice. Until recently, naval guns had usually a blunt knife edge for their front sight, and a rather wide and deep notch for their rear sight. In guns very lately made, the knife edge is generally sharper and the notch narrower; but whether this will result in better shooting remains to be seen. In the case of a test applied to the 16 first and second gun-captains of the *Richmond*, it was found that the accuracy of their pointing was not materially altered by changing from the comparatively sharp edge and narrow notch of the Gatling's sights to the broad edge and notch of the 9-inch S. B.*

If a gun is pointed with the eye close up to the rear sight, and the eye then moved back somewhat, the first pointing will appear erroneous. It was found, for example, that if the 3-inch B. L. R. was pointed at the water-line of a ship some 800 or 1,000 yards distant, and the eye then moved back about 4 feet from a close proximity with the rear sight, the gun appeared pointed too low, and the bar had to be lowered about 75 yards to make it seem right. This was tried by a number of officers who were present, and they all agreed as to the phenomenon observed.

The importance of this in putting the sights on guns will not fail to be appreciated. If a gun has been ranged and sighted by firing it, and if the eye of the person who pointed it was always, during the process, back in the position which the gun-captain's eye will occupy when using the gun in a seaway, then the marks will be in the right place. An error of 75 yards in range is not important in firing at targets near by, but this error, when firing the 6-inch B. L. R., at 1,700 f. s., at a target only 1,800 yards distant, will displace the point struck 8 feet vertically and at ranges slightly greater would cause the shots to miss ordinary targets altogether.

There is another matter closely related to what has just been said—the question of how to put sights on guns—which may now receive attention. According to whether sights will be used coarse or fine—to how much front sight the gun-captain will habitually take—their positions on the gun will vary. It is not enough to simply decide how they shall be put on. We must make sure that their use at all times is in accordance with the manner in which they are put on the gun. If the gun is fired for ranging under circumstances identical with those of its subsequent use at sea—which will perhaps never be the case—the sight-points will come in the right place; but if the marks on the bar are reached by calculation, they will be put on fine, and, of course, should be so used. It may perhaps be better to put the sights on fine, and then lower the rear sight by proper amounts according to the roll, condition of light, etc. It must be fully recognized, however, that the sights of guns firing on board a quickly-rolling ship can not be used fine. The whole of this matter requires careful attention and a clear settlement, the principal thing in view being always the best and most convenient manner of using the sights in service. The general tendency at present seems to be to put sights on naval guns coarse. The Hotchkiss firm announce, for example, that all their guns are coarse sighted.

---

*The test here alluded to is made in the following manner: A pair of gun-sights are firmly mounted in some convenient place, and a board put in the line of sight some 30 feet away. Then a visiting card with a dot on it is held against the board and is moved until a man looking over the sights says the dot is in the line of sight. A pin is then run through the center of the dot and marks the board behind. This operation being repeated as often as considered desirable, without moving the sights, the dispersion of the pin marks on the board is a measure of accuracy.

Guns are either central or side sighted; that is, their sights are either on top or on the side of the gun. As the gun itself furnishes a well-marked line to the eye, central sights are usually the best; but these become inconvenient as the clearance angle is reached, and then side sights are used. There is a question as to the distance between sights—the sight-radius, as it is often called—which is of importance, and which affects central and side sights equally. There is reason to suppose that, as the distance between sights increases, the errors in pointing—in placing the line of sight on the target—will diminish. And if it may be assumed that the error of the eye in pointing a gun consists in taking too much or too little of the front sight in a linear (as opposed to an angular) sense, it follows that these errors will diminish in simple proportion as the sight radius increases. As bearing out this view, the following experiment may be adduced:

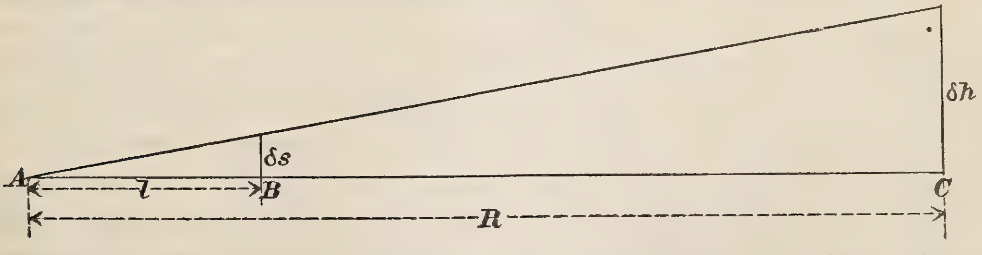
In the summer of 1887 the 16 gun-captains of the *Richmond* were put through the eye test with a fixed line of sight which has already been described, with the sights of the 9-inch S. B., when these were mounted at their usual distance apart and also when this distance was doubled (39 inches in the first case and 78 inches in the second). The average vertical and sideways dispersions of the sets of 5 pin points, marked in the manner already described, were as follows:

	Vertical dispersion.	Sideways dispersion.
	Inch.	*Inch.*
Long radius	0.26	0.18
Short radius	0.40	0.31

Here the dispersions, though not reduced quite one-half by doubling the sight radius, are reduced in nearly that proportion. In consequence of what has been narrated permission was asked and obtained of the Bureau of Ordnance to move the front sights of two of the *Richmond's* 9-inch S. B. to the muzzle of the gun. This more than trebled the length of the sight radius, but, in a target practice with the sights so placed, there was no improvement in the practice. It was raining, however, upon the occasion, and the circumstances were all against close shooting. The gun-captains when questioned said that they liked the long-sight radius better than the short one. Whether, upon the whole, the sight radius should be long, and how long it should be, can be decided only by carefully recording the practice of a considerable number of men using radii of different lengths.

The question of the degree of coarseness in the use of gun-sights at sea has already been touched upon, and the delay in firing the gun, which is an allied question, may be noted here. The time which elapses between the instant when a gun captain begins to try to fire a gun and the projectile's leaving the bore is a measurable and important datum. It is sometimes called the firing interval; and though it is perhaps impossible to reduce it to zero, its smallness and constancy is the most important quality—after certainty of action—in a firing device. The interval between the gun-captain's beginning to pull the lock laniard and the explosion of the primer, with the old navy percussion lock, was 0.13 second. This is more than one-eighth second, and thus it becomes apparent, without adding the time necessary for the charge to light and the projectile to get out of the bore, that, if the gun captain begins to pull the lock string of a gun supplied with this device, when rolling 1° per second, when the line of sight is on the hammock rail of a ship 20 feet high, when 1,000 yards distant, the shot will strike in the water short of the ship. The only way of correcting in practice for such errors as are here pointed out (and there can be no doubt of their importance practically) is to put the bar too high or too low by a proper amount.

Practically speaking, the adoption of higher power in guns—high velocities and long projectiles—has not altered the degree of skill necessary in gun captains. The subject of the consequence upon vertical targets of errors in placing the line of sight may, without sensible error, be regarded in the following manner in the case of the short ranges and flat trajectories which rule in the practice of naval guns.



Supposing in the figure that the rear sight is at A, the front sight at B, and the target at C, it is apparent, by similar triangles, that if δs be an amount by which too much or too little sight is taken, δh will be the resulting error in placing the line of sight on a vertical target at a distance R. These quantities are connected by the relation

$$\delta s = \frac{l}{R} \delta h\,;$$

and we have also, $\delta s = l.\ \delta x$, δx being the change in angle of elevation due to the small error δs in using the sights. Now, the changes in the length of the line of sight—the line drawn from gun to target—are so small for the errors of pointing here contemplated that the projectile will pierce the vertical target at the same point with the line of sight. In other words, with flat trajectories and with small differences of height between gun and target, we may throw the curved trajectory out of consideration altogether, and may, when thinking about errors on a vertical target, carry the line of sight only in our calculations.

Finally, as to the accuracy with which guns may be used: The height of the bull's-eye of the army 1,000-yard target for rifles is 45 inches, and a few of the best marksmen will put all their shots into it. The Hotchkiss 3-pounder requires (see Hotchkiss publications) 58 inches vertically to catch all its shots fired at 1,000 yards range on the proof grounds, where, as in prize rifle-firing at the butts, everything is favorable to accuracy. The English high-powered 12-inch B. L. R., on the proof grounds, can put all its shots, fired at 1,000 yards' range, on a belt 38 inches across vertically; while at the same range and with present degrees of skill, an average naval gun afloat will put all its shots, when the rolling motion is not great, on a belt about 32 feet high. This latter statement is based upon an examination of the records of the target practices of a number of ships when at sea. It would appear from the width of this belt that there is not really much difference in the accuracy of guns when used in service conditions. There are differences in the accuracy of guns, but we must go to the proof grounds to discover them. The errors which occur when they are used at sea, and errors entirely removed from any question as to the ascertainment of the range, are so large as in great degree to mask the gun's proper errors.

With regard to the selection and training of men to be captains of great guns, it appears that two or three simple rules are all that we require to govern us. In the first place, before any man, otherwise suited to the place, should be made a gun captain he should have proved himself a good snap shot with rifle and revolver. It is not necessary to inquire here how or where he will get the necessary training. That must be got in whatever manner is possible. The principle is laid down, and it is always admitted by navy officers, that a man should be a good snap shot before he is made captain of a great gun. Then, the gun's crew, being made up by the selection of proper men, the captain included, the training of the gun's crew as a unit must begin. After they have learned to handle the gun properly without a load they should be required to fire a string of shots at speed at a target at a known distance. The result they show, the closeness of the target they have made, taken together with their speed of handling the gun, is the measure of their quality as a gun's crew. When we have thus formed the best gun's crews we can of the material at hand the drill of the ship's company begins, the general quarters, or fire discipline, or whatever we choose to call it. During such exercises the whole ship's company will be at their stations for battle, the ship will be moving rapidly about and the range changing, and, so far as making a good target is concerned, it will be as much a matter of control as of marksmanship.

CONTROL.

By good control of the ship's battery its fire is made effective. This branch of naval gunnery has not of late received the attention which it requires. When ships are moving rapidly the distance between them will often change at the rate of 15 or 20 knots per hour, and will at times change at the rate of 30 or more knots per hour. A relative speed between two ships of 15 or 20 knots per hour means that the distance is changing at the rate of about 510 or 680 yards per minute. At medium ranges the sight-bars will require alteration every 6 or 8 seconds. Thus the sight-bars will be continually moving. The speed of motion of the sight-bar of the 6-inch B. L. R., when fired with a muzzle velocity of 1,700 foot-seconds at a target whose distance is 1,000 yards and is changing at the rate of 30 knots per hour, being more than 1 inch per minute—enough to make its motion visible to the eye.

The difficulty thus presented, and it is probably the greatest occurring in the whole range of naval gunnery—or in gunnery of any kind, indeed—is not one for the marksman. The office of the pointers of present naval guns is to keep their guns pointed all the time, and to fire them as often as they can; as often as the safety attachment will allow. A member of the crew must keep the sight-bar in the right place. And, it may be repeated, the task of the marksman or pointer is not made more difficult by the continual motion of the sight-bar. It is the officer who controls the battery, who works it or handles it, who has difficulty in keeping track of the target, in keeping each gun in the ship always advised of when the target is coming within its horizontal arc of train, and of the range to be used to hit it at all times. To get the sight-bars into the correct position and pour in a heavy fire when they are right is the object of control.

In order that the practice of guns, under any circumstances, shall be very effective, two things are necessary: (1) that the centre of the group of shots fired, or the *centre of impact*, shall coincide with the target's centre, and (2) that each shot shall deviate as little as possible from the centre of impact. The position of the centre of impact depends upon the person who controls the position of the sight-notches of the guns, while the degree of closeness of the group of points of impact about their centre is dependent upon the skill of those who pointed the guns. The importance of keeping this distinction clearly in view and the necessity of separately improving each of these essentials to the utmost possible can not be too strongly emphasized.

The distance of the target, as ascertained by triangulation from aloft or elsewhere, is usually communicated to the battery in naval gun practice; and this distance, after being more or less corrected, is used at the guns. The method is somewhat loosely carried out at times; but, in its broad outline, is what must continue to be used in ships. But the sight-bars of the guns, which furnish an excellent means of finding the range—the only true means indeed—must not be neglected. What they say, as indicated by where the projectiles are falling, must be closely followed, and intelligently interpreted.

It appears that none of the guns now in use could be so quickly adjusted as a Gatling or Maxim, for, with one of these, by watching the bullets as they strike almost like a stream of water from a hose, we could quickly get the correct sight. In a similar manner, if one man can control all the guns of a battery as regards the position of their sight-notches, and can also control their fire as to speed, he can, if he is skillful, direct the fire to the best effect of which it is capable. If his skill is so great and the previous drilling of the battery so perfect that he has caused the centre of impact of the shots fired to coincide with the centre of the target, the fire can be improved only by improving the skill of the gun-captains in pointing, or that of the crew in handling the gun quickly.

It may appear that what is urged here is impossible of accomplishment; that a battery of guns at sea can not be in this way subordinated to one will. And yet it is what we have tried to do ever since guns went to sea in ships, and is what we try to do now. Outside of any skill in marksmanship on the part of the gun-captains, two things are necessary for the success of the plan: (1) the guns must all shoot alike, and (2) an officer at a station where he can see must be able to control the guns as to the position of their sight-notches, and as to the speed of their firing. He must be able to cause the fire of the battery to dribble slowly while he feels the way to a correct range, and to fire the whole battery by command nearly like a single gun.

In all land artilleries on the continent of Europe they have now what are called Rules of Fire. These might be called the battery drill, being a system of orders and instructions by which the drill of the battery when firing at targets is carried on. The rules lay down the orders which shall be given, and the various steps by which the correct range shall be ascertained when firing different kinds of projectiles at stationary and moving targets. The refinement with which details are entered upon is surprising to one who reads a system of rules of fire for the first time, and yet it is not greater than that found in many manuals of drill regarding comparatively unimportant things.

The fire of guns at sea is, however, a much more difficult matter to deal with than their fire on shore; the speed of the swiftest target on shore, a squadron of cavalry, being nearly always exceeded afloat. But the navy which first grapples with the problem of the control of guns and solves it effectively and practically will place itself. for a time at least, ahead of all others in fighting efficiency.

In finding the range by means of the sight-bars of a battery of guns, it is usual to feel the way to a first approximation to the correct range by firing, as rapidly as may be convenient, a succession of single shots in one of two ways. One way is called the method of *successive means*, and consists in—having observed that a first shot fell short, say—increasing the range vigorously for the second shot, so as to be sure of going beyond the target at the next fire, then using the mean range of the two inclosing the target for the third shot, and so on, thus continually narrowing the belt in which the target is situated. The second method, called the *progressive* method, consists in dropping the first shot short (usually), and then feeling the way up to the target by successive increments (or decrements) of range until the target is inclosed in a belt of a certain width as before. The magnitude of the changes of range by which to proceed in following these processes, and the narrowness to which we may finally contract the belt, or *fork*, as it is usually called, depend evidently upon the errors of the gun in use.*

Suppose, for example, we have fired a shot at a target whose range is known only within wide limits, and have observed it to fall short. Since the centre of impact, for the actual adjustment of the bar, is equally likely to be short of or beyond the point struck by the projectile, it is probable—is more than an even chance—that the range should be increased, provided, as is usually the case in practice, that the errors in our distance-estimation are larger than the range errors of the gun. As the particular shot observed is equally likely to be short of or beyond the centre of impact for the adjustment of the bar used; and as the shot fell short, the probability that the range should be increased is greater than one-half. Further than this we can not go with the knowledge at hand. If we know how much the shot was short of the target, and know also the gun's range error, we can better estimate the advisability of an increase of range and its amount, but not otherwise. If a second shot, fired under identical circumstances, also falls short, the chance that the centre of impact is beyond the target—the chance that we shall err in increasing the range—is less than $(\frac{1}{2})^2$, or one-fourth.

If we have reached a first approximation to the range, either by triangulation or by inclosing the target in a fork by firing two or three shots, the subsequent adjustment of the range, by the observation of the fall of a number of projectiles, is a simple matter in the case of a stationary target. We have only to see that one-half of the projectiles strike below or short of the point where we want to make the fire hottest. In the case of rapidly moving targets the matter is much more difficult; but here an effective discharge of all the guns might be got by feeling the way up to the target by the progressive method until a shot falls beyond; at that instant, all the guns having followed the target closely with their bars in the same position as the range-finding gun, order the whole battery to fire at will together. To execute this scheme will require good marksmanship on the part of the gun captains, quick and sure work on the part of the gun's crews, good judgment on the part of the officer controlling the fire, and quick and sure communication between him and the guns. All of these things can be had, and the method of firing advanced, though extremely difficult of execution, is perhaps as simple as any which can be devised.

---

* A system of Rules of Fire adapted to the use of guns afloat will be found on p. 217, Text-Book of Ordnance and Gunnery, Naval Academy, 1887.

The idea which underlies the whole subject of the handling of sight-bars by observing the points of fall of projectiles is this: For any adjustment of the bar there is a *mean* trajectory, a trajectory which connects the gun with the centre of impact for the actual adjustment of the bar; and the centre of impact may be conceived to have described around it as a centre an ellipse or rectangle, on which surface alone the fire of the gun can fall. For guns afloat, with men of fair skill, at a range of 1,000 yards, this ellipse or rectangle is about 300 yards long in range by 30 yards across. On this area, with the adjustment of the bar in use, the projectiles may fall, and outside of it none will fall. The density with which the projectiles are falling at any part of this area is such that, if a certain fixed area would receive 30 shots in a given time if situated at its centre, then it would receive only 20 shots in the same time if moved away 50 yards in range, and would receive only 1 if moved 150 yards in range, or to the edge of the rectangle. The object of control, as has already been pointed out, is to bring the dense part of the area on which the shots are falling to the centre of the target.

The subject of the control of guns leads naturally to an examination of what ranges should be marked on sight-bars—by what increments the changes should proceed. Fifty years ago the first mark put on gun-sights was what was called point blank—the distance the shot would range before striking the water when the gun was fired at level from its port on board ship. Presumably it was considered unnecessary to put on the shorter marks. And a hundred years ago, when there was a great deal of sea fighting, the Fighting Instructions of the British navy forbade captains to engage until within point-blank range. Probably the difficulties of control at longer ranges were held to be sufficient to make it unwise to expend ammunition at such ranges. A change of $\frac{1}{10}$ inch in the position of the sight-bar of the 6-inch B. L. R., at 1,000 yards, will throw the line of sight, if it had been adjusted to the centre of a target 10 feet high, off the target, and a change of $\frac{1}{10}$ inch is here equal to 100 yards' range. At 500 yards' range it takes $\frac{2}{10}$ inch to throw the line of sight off, or 200 yards' change; and at 100 yards' range it takes 1 inch of the bar, equivalent to a change of range of 1,000 yards, to throw it off. At 2,000 yards' range, $\frac{1}{20}$ inch, equivalent to about 50 yards' change of range, will throw it off.

There is here ground for the examination of this whole matter. Control occupies a position midway between marksmanship and tactics. A broad view of naval tactics—a view taking in all naval weapons of both offense and defense—tells us what the guns will be called upon to do, and control tells us whether or not we can do this, and how best to accomplish it. It includes laying down the drill to enable us to do what tactics indicates as best. Finally, marksmanship, which tells us what our men can do—whether they can execute effectively any plan we may be led to propose—and how best to teach our men how to shoot, can not be neglected in the study of tactics or control. The three, though in some sense separate, are yet very closely related. No one can reason about naval tactics without knowing or assuming something about marksmanship at sea.

TACTICS.

The subject of gun-tactics is the most extensive division of gunnery. It is sometimes said that there is no tactics for existing ships; and, though it is true that no code has received the approval of all, or even of a large proportion of naval officers, yet the very existence of war ships implies the existence of tactics. No one who has an opinion about how a ship of war should be designed is without conclusions as to tactics. War ships all over the world are much alike, and their similarity implies conclusions as to their fighting tactics.

Existing guns, in the hands of gun-captains of fair skill, will put about one-fourth the shots fired from them when afloat into a target 12 feet high and of indefinite length when at 2,000 yards' range, the range being accurately known. This range might thus be called the Opening Range, it being unlikely that, in circumstances of service, when the distance is imperfectly known and men are more or less excited, we shall get many hits at greater distances. This range is again that at which present battle-ships can penetrate their own thickest armor. With normal impact these ships can penetrate up to 3,000 or 4,000 yards; but when we take account ot the obliquity of impact which will occur to a greater or less degree, we may lay down the rule that 2,000 yards is about the limit of range for penetration.

The most significant range for a naval gun is that at which, for purposes in hand, its trajectory is flat. Present high-powered guns will range about 1,100 yards without the projectile rising higher than 12 feet above the line through gun and target. If, then, we always point at the water-line, it does not matter whether we know the range of a target 12 feet high and upward or not, if we know merely that it is within 1,100 yards. This we might call the Dangerous Range, following the analogy of the term dangerous space.

What, then, will be the range of future naval battles? The ram says it must be zero distance, the torpedo wants it some 300 or 500 yards as a maximum, and the gun puts its maximum at some 1,500 or 2,000 yards with heavily protected ships. And the gun engages to do good work anywhere about within 1,100 yards—as accurate work as the torpedo will do at 300 yards, perhaps. This, then, is the *zone* of the gun—from say 1,200 to 400 yards. It reigns supreme within these limits of distance, and with well-trained gunners will here give a large percentage of hits.

The angle between the keel-line of a ship and the line of fire—the line drawn from her to her adversary—is an important one. This has been called the Presentment Angle, and it controls the angle of impact of enemy's shot, and thus the thickness of our armor to be penetrated, the limit of bearing to which we can allow the enemy to get without preventing our guns from training, and also the limit of nearness to which we may allow him to approach with impunity if he holds bows-on and is evidently intending to ram.

The relative power of the guns and protection of a ship—her protection of her own life and of the lives of her crew—constitute a large part of what is important in a fighting sense about her, and controls her fighting range. The *Constitution*, for example, built in 1797, and the *Atlanta*, built in 1883—nearly a century apart—exhibit very marked differences in relation of guns to protection. The table gives the main batteries of the two ships, the one given for the *Constitution* being that carried when she fought the *Guerriere :*

	Constitution.	Atlanta.
Guns carried	32 long 24's 22 short 32's	6 6-inch B. L. R. 2 8-inch B. L. R.
Number of guns	54	8
Weight of single broadside	684 pounds	800 pounds.

With her long 24's the *Constitution* could probably just about penetrate her own water-line—some 22 inches of oak—at 1,000 yards' range; to penetrate with the short 32's she would have to approach nearer. The *Constitution* is, then, completely protected against the fire of her like at ranges greater than 1,000 yards; and this extends, it should be noted, to the ship's life—her buoyancy and stability—and to the lives of her crew, for the thickness of the *Constitution's* side over her gun-deck was some 18 or 20 inches.

The *Atlanta's* 6-inch guns can penetrate, at 1,000 yards, a thickness twenty times that of her side at the water-line. And the 8-inch guns can penetrate, at the same range, about 14 inches of iron. It may be further observed that the $\frac{5}{8}$-inch steel at the *Atlanta's* water-line has just about the same resisting power as the 22-inch oak of the *Constitution.* Thus, while the defensive power at the water-line has remained about the same, the later ship has a battery power which, considered with reference to penetration alone, is twenty-five times stronger roughly.

As regards the size of the two ships here compared it may be added that the *Atlanta* is about one-half larger; but their military duties, their employment in war time, are identical. They are both, in the military sense of the term, frigates; the duties of both are to accompany and assist the battle-ships, to carry them information and stores, act as lookouts for them, and they are also destined to attack the enemy's commerce and guard or convoy our own.

Thus the *Atlanta* and all *protected* ships can penetrate their likes when they are still hull-down on the horizon; while battle-ships, or *ironclads*, as they are often called, must approach within from 2,000 to 4,000 yards before they can hope to make any serious impression. This was not the case formerly. Ships-of-the-line, frigates, and sloops all fought at the same range. The 74's sides were thicker and her guns were heavier than the frigate's. But the value of the ratio

$$\frac{\text{Power of Offense}}{\text{Power of Defense}}$$

at a fixed range was practically the same for ships of war of all classes, and was unity—or the gun's power was just enough to penetrate—somewhere between 500 and 1,000 yards. There is perhaps no reason, in the nature of things, why this ratio should be the same for all classes of ships; but the sharp difference between former and recent practice is of interest. If the distinction is to endure, the tactics of our battle-ships and frigates must be different.

The power of a gun should be such that it can overcome the defensive structure to which it will be opposed, and greater power is not only useless, it is harmful. Because the problem comes to the tactician, when designing a ship, in this way. He has such a weight to put in guns and their equipments; and whether we regard the number and weight of shells which will hit, or their bursting effect, the result will be much the same whether this weight be put in a few large guns or in many small ones, providing the speed of serving them is the same. The table shows at a glance the tactical value of the 10-inch and 5-inch guns.

Gun.	Weight.	Penetration.	Weight of projectile.	Weight of bursting charge.
	Tons.	*Inches.*	*Pounds.*	*Pounds.*
10-inch	24	20	480	16
5-inch	3	10	60	2

Here we fill out the spaces for the 5-inch gun by dividing the weights for the 10-inch gun by 2^3, or 8. And evidently, for each 10-inch gun, we may carry, so far as weights and volumes occupied are concerned, eight 5-inch guns.

We have of late shown some disposition to return to the numerous light guns of former days, but as yet no disposition to increase the calibre of guns of fixed weight. Sir William Armstrong, at whose works at Elswick the Italian cruiser *Piemonte*, of 2,500 tons, has recently been built, asserts that this vessel, armed with rapid-fire guns of 6 and 4¾ inch bore, can throw a greater weight of metal (and of bursting charge) in a minute than any of the great ironclads of Europe, some of which are five times her size. To emphasize this rather striking statement, he says that the 4¾-inch gun has fired 10 rounds in 47 seconds, while it took the ordinary gun 5 minutes 7 seconds to do the same thing; and also that one of these guns struck a target 6 feet square, at 1,300 yards range, 5 times running in 31 seconds. The armament of this ship and of others of recent date indicates a disposition to use more numerous and lighter guns; but there is not yet visible here or elsewhere any disposition to make guns of larger calibre on a fixed weight—to diminish their "power." And yet many naval guns now afloat, particularly in unprotected ships, have power greatly in excess of that of the targets to which they will most usually be opposed.*

The tactical value of a gun depends upon the number of shots it can put into a standard target in a fixed interval of time, upon its power of penetrating or smashing targets, and upon its mine power. When mounted on board ship we must add to these the magnitude of its arc of train, both vertical and horizontal, and the speed at which it can be served. The first of these qualities—that of putting a large number of shot into a target in a given time, belongs in a higher degree to small than to large guns; because, although the larger shot are usually less deviated by the accidents of flight, yet they cannot be delivered so rapidly from the same total weight of metal in guns. The second—that of penetrating and smashing targets—increases with the calibre. And the mine power of shells increases much more rapidly with the calibre—nearly as its cube.

The question of how a given weight of guns shall be disposed, as to the calibre selected, merits a close attention, for it is the tactical question regarding guns which is now the most pressing one. We have 50 tons to allot to guns in a ship; shall we put it in 2 10-inch guns, 10 6-inch guns, or 16 5-inch, of the present system; or into 3 15-inch smoothbores, 7 11-inch, or 13 9-inch of the Dahlgren system; or into 23 36's (6.2-inch bore), or 46 18's (5.2 inch) of the system proposed by Robins one hundred and fifty years ago?†

The question is one of range. At what range are modern vessels, armored and unarmored, expected to fight? A logical solution of the question of the offensive and defensive powers of a ship of war can not be reached without assuming what the fighting range will be. The writer's belief is that gun contests, while the armor and armaments of ships remain as they are now, must take place, for the most part, within 1,000 yards, because we can not do much hitting at greater ranges. The pressing questions on the construction side of gun tactics are, shall we have numerous guns or a few large ones? And, shall we go on diminishing calibre or enlarge the bores of our guns at the expense of penetration and flat trajectories? We can not stand still. We must move one way or the other.

---

*Robins, in "A Proposal for Increasing the Strength of the British Navy, by Changing all the Guns, from the Eighteen Pounder Downwards, into others of Equal Weight, but of Greater Bore," printed in 1747 in his "New Principles of Gunnery," makes an argument which is full of interest to the tactician of to-day.

†See Robins's letter referred to above.

With regard to the question of protecting our 50 tons of guns, variously disposed, it may be observed that, while we can more easily protect the heavy guns by armor defenses, the light ones gain the defense supplied by dispersion—that sought by skirmish lines. And when we reflect that there is not afloat to-day a single gun which is protected sufficiently to keep out its own fire at ranges within about 1,500 or 2,000 yards, we must admit that the guns must be dispersed. A denial of this must rest upon the assumption that ships will use their guns for the most part at ranges greater than 1,500 to 2,000 yards, and the argument against much use of the guns at so great ranges is that they can not hit, partly because it is harder to hit a target at 2,000 than at 1,000 yards, but principally because the distance-finding is much more difficult. The lessons of history and the teachings of common sense indicate that great stress should be laid on what was formerly called point-blank, and has here been called the dangerous range—300 to 400 yards in former times and 1,000 to 1,100 yards now.

The development of the use of high explosives in shell-charges remains to be referred to. If shells carrying charges of high explosives and with delay-action fuses can be fired through targets of respectable thickness, this new feature of gunnery will undoubtedly hasten the drift of opinion already set in in favor of the wider diffusion of armor. But it must be remembered that the mere getting a shell through a ship's walls is not enough; it must be burst on her decks. A shell moving at the rate of 1,500 f. s., has a margin of $\frac{3}{100}$ second in which to burst while traversing a deck 45 feet wide, and of $\frac{1}{5}$ second while traversing one 300 feet long. And any one who will analyze carefully the gun contests of the days of shells—such as Tegetthof's action off Heligoland, or Farragut's actions—will see how very few shells have burst between decks.

As we look back across the three hundred years which includes the history of naval guns, we see everywhere the evidences of change—of the continual balancing and swaying to and fro of the powers of offense and defense. Two hundred and fifty years ago guns were 40, and a few even 60, calibres long, and, as should be the case with any such gun, they had large charges (one-half the weight of the projectile or more) of slow-burning powder. Later on the guns had shortened, and in Dahlgren's time were only 13 to 15 calibres long, and of large bore for their weight. Now again we have them 35 calibres long and upwards; and though naval opinion is certainly in favor of putting a fixed weight in a larger number of guns than ten years ago, there are as yet few expressions of opinion in favor of larger calibres on a fixed weight. Yet this latter follows almost with certainty the former. Robins's views, expressed in 1747, in his letter already referred to, were that the guns were more powerful than necessary in view of the targets to which they would be opposed, and these views were completely carried out in the century following his letter. And then, seventy or eighty years later than Robins, we find Sir Howard Douglas laying the blame for the English defeats in 1812 to his views on gun-building. Naval officers must not be seduced into believing that any of the present features of our armaments and protection are permanent. They must watch for and anticipate each change, and by keeping ahead in the changes continually going on, keep their ships better than any others.

The part of gun tactics which deals with the movements of ships in battle, as controlled by the disposition of their guns and armor, is the complement of the part which controls matters of construction. Our means must be perfectly adapted to our ends, and no feature of naval construction should be adopted and put afloat without a full examination of its effect upon the ship's motions and efficiency in battle. We are accustomed to regard the original monitor merely as a very powerful war-ship built just in time to make her influence felt tremendously. But she was the most extraordinary ship which ever appeared, her new tactical features consisting in two things: (1) She was practically indestructible by her own fire *at any range;* and (2) her powers of offense and defense were equal on all arcs of the dumb compass. Or, to put this latter quality in another way, except as regards ramming, she was independent of the presentment angle (the angle between her own keel line and the line of fire).

The tactical situation of two ships in combat is completely defined when we know the angle of presentment of each and the distance between them—three data. If we have a series of records of these three data at successive instants we have the whole story of the fight. In the *Kearsarge-Alabama* fight, for instance, as the two ships moved at the opposite ends of a diameter of a circumference, the two angles of presentment were always 90°, and we require to know only the range in addition to completely understand the whole combat.

And this statement is true, it would appear, whatever tactical features ships may possess. It is as true of the days of sails and wood as in those of steam and iron. Throughout the period of sails ships which were well handled tried to keep in the dead angles of their antagonist's guns during approach, and at other times also as much as possible. A ship laid across her antagonist's bow or stern was not only able to pour in a very destructive fire, but was also in a very sheltered position. In our time, however, one feature regarding the presentment angle has arisen which had not much significance formerly. A ship which has her adversary five points before or abaft her beam, while still able to use all or nearly all her guns, has *doubled* the thickness of her side to be penetrated, besides having largely increased the chance of deflecting shots; while, if held one and one-half points before or abaft the beam, which was formerly about the limiting arc of train of guns, the thickness to be penetrated is increased by only one-twentieth.

It appears likely that naval duels in the future may, so far as the gun contest goes, resemble closely the fight between the *Kearsarge* and *Alabama.* In this combat the *Kearsarge* steamed straight for the *Alabama's* broadside until, fearing the effect of the broadside of the latter, the *Kearsarge* put her helm over, brought her guns to bear, and steered for the *Alabama's* wake. If she had steered ahead of her, a running parallel fight might have occurred; but as it was, the *Alabama* went ahead with her helm over to prevent the *Kearsarge's* getting into her wake, and as each ship was trying to get into the other's wake they moved in the circumference of a common circle.* The vessels were of the same size, and had probably about the same handiness. The reason that the *Kearsarge* did not steer ahead of the *Alabama* was doubtless because she feared her ram.

This fight is ideal in its simpleness, and from the fact that a ship when approaching an adversary, as in this case, can not well pass ahead of her, from fear of her ram, it looks very much as if these tactics would be repeated. The *Alabama* could answer the *Kearsarge's* steering for her wake in no way but as she did. She could not lie motionless, and she could not have put her helm the other way. It is true that neither ship gained any tactical advantage, except as the range chosen (from 1,100 to 700 yards) may have suited her; and thus the battle may not teach us how to gain such, but still it is most instructive as probably representing a type of future sea duels.

The presentment angle is an important tactical datum as regards the ram and torpedo as well as the gun. The captains of the *Kearsarge* and *Alabama* were thoroughly appreciative of the power of the ram, but both chose to use the gun. Suppose, now, one had chosen the gun, and the other had chosen to hold bows-on the enemy and go at full speed. The gun, so far as its arc of horizontal train goes, is largely indifferent to the presentment angle, all the way around the compass, and it greatly prefers a range within 1,100 yards. From perhaps about 700 or 800 yards inwards it will give a very large percentage of hits on targets of ordinary size in smooth weather. The ram, on the other hand, is most exacting. The range of the angle of presentment of which it permits is extremely small, and it permits of but one distance. If, then, the gun can reach out about 1,000 yards anywhere in a sector comprising nearly 360 degrees around the ship, and the ram can touch only the few points in a small piece of a circular arc lying against the ship's cutwater, surely an accommodation can be reached. The torpedoes—those carried by the ship herself—can reach anything within their arc of horizontal train and not more than from 300 to 500 yards distant.

---

* A ship is very defenseless against a ram in her wake.

The attack of the ram must be avoided or properly countered, it may be added.

If a ship intending to ram is in the wake of another, the ship ahead is in no very imminent danger; is not in a position from which she can not extricate herself (without great excess of speed) until the distance between them is about two tactical diameters. For long ships this will be about 1,200 yards. Similarly, a vessel having a ram broad on one bow can always turn and meet the ram bows-on until the distance diminishes to less than about eight-tenths tactical diameter, or for long ships to less than about 500 yards. In gun contests, handiness is of extreme importance, controlling, as it does largely, the angle of presentment.

A ship, then, which desires to use her guns while her adversary is heading for her with the intention to ram, can keep her engines going fast enough to have the ship under control, and hold her adversary about 5 points before the beam, thus making it possible to fire all her guns. Then when the range is about 500 yards—and the guns having been all fired at this short distance—she turns and meets the ram bow to bow.* A vessel well trained in advance to use her guns in this way could hardly fail to make an impression—to gain an advantage. And whether she made an impression or not, her next step is pretty clear; she turns towards her enemy, and steers straight for him. At ranges of 500 yards and less the small-arm and machine-gun fire would be very effective; and as the broadside guns can not often be used at this time the crews of these guns should be trained to quickly take covered positions from which to fire at the advancing ram.

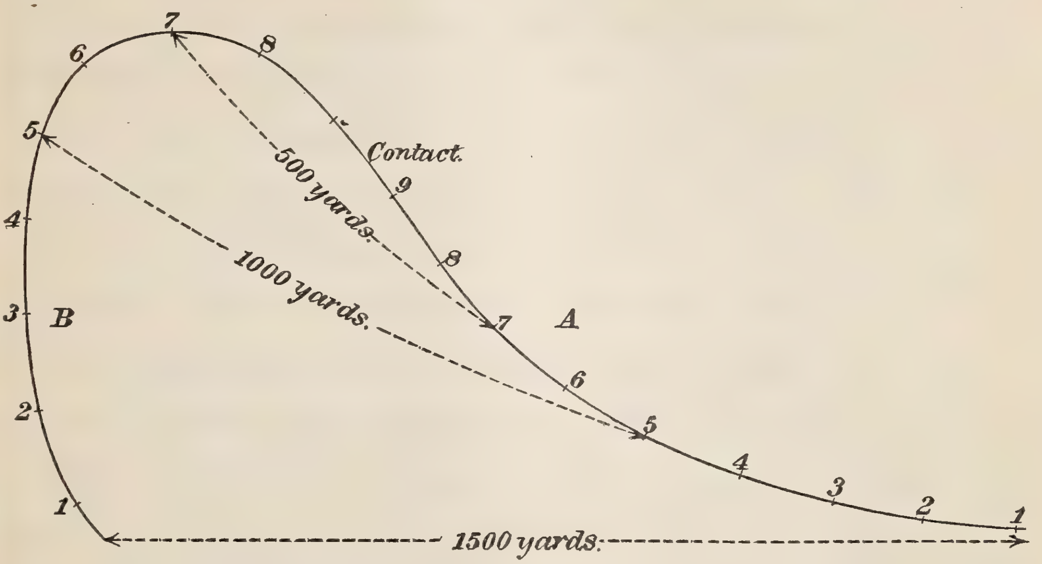
The subject of the effect upon gun practice of the powerful helms now supplied to ships is naturally raised here. With present gun-carriages there is no reason why the guns should not catch the target with fair ease, so far as the horizontal swing of the ship goes; but if the helm is suddenly changed the vertical swing will be great, and until the helm has been steady for a moment, will upset all calculations. It might be of advantage to teach the helmsmen to steer by a dumb compass—to hold an object in the water on some point of the dumb compass, and every effort should be directed to making the changes of helm as few as possible in action—to make the time under a steady helm (not necessarily amidships) as long as possible. Ships formerly would bring by the wind when in chase in order to fire their broadsides, but the sudden change of heel of the ship so upset the men at the guns that little or no good was ever done in this way.

It has been suggested that gun contests in the future may very probably resemble the *Kearsarge-Alabama* fight, and it remains to suggest what may be the movements of two ships, one intending to use her ram, and the other desiring to make an impression with her guns first.

---

* It might be judicious to lay down a tactical law that however the power of guns may vary, their dangerous range shall always exceed the limit of safe approach of 500 yards, thus indicated by the ram. It would probably be best to extend the limit from 500 to, say, 800 yards.

It appears not unlikely that ships so circumstanced may move as represented below. Here the nine successive positions of A represent



the movements of the rammer, and the nine successive positions of B the corresponding positions of the ship which wants to get in some work with her guns. A is represented as holding bows on B all the time; B, at position 1, has A broad on his quarter, and is going full speed, while holding him on that bearing and firing her guns. At position 5 the distance has been diminished to 1,000 yards, and A is right abeam of B. Here B may as well slow his engines to full steerage way, and bottle up steam for the sudden turn which may be required. B, however, continues to turn inwards toward A, so that when at 500 yards range (position 7) she has him broad on the bow. At about this point the broadside guns will no longer bear, and the small-arm fire will begin to be effective.

No explicit mention has here been made of the protection of the two ships. A ship which will be handled like B here ought certainly to have considerable protection for her guns' crews. A does not need this so much. The defense of a ship, indeed, ought to follow the offense. She ought to be defensively and offensively strong on the same arc. And this equilibrium should be based, not upon the power of any one weapon upon certain arcs, but upon the power of the ship as a whole. It may also be noticed that no mention has been made of torpedoes, and though the fact that the subject of torpedoes is not before us may be held to be a sufficient reason for this, it may be added that a consideration of the torpedo, as well as the gun and ram, will not radically change what has been advanced.

The examination of the relations and possible changes of the presentment angles and range as between two ships comprises the whole subject of tactics in duels. This was true formerly and is true now. In the days of sail, ships gained advantages by choosing the range according to the power of their guns, and by varying the presentment angles when the captains had quicker wits and quicker ships than their adversaries. Historians of naval wars discuss at great length the question of how the range during an action was suited to the guns of the two combatants, of how the approach was conducted, of the history of the presentment angle during this interval, and of how one ship or the other so adjusted the presentment angles of herself and her opponent as to be out of fire herself and yet be able to pour in an effective fire. And it is clear that the manœuvring stage of naval duels of the future can consist in no more than this. When the vessels are once close together—within half the dangerous range of each other, say—the battle is decided by rapidity of fire. In former days a ship would approach from to windward, keeping in the dead angle astern of her opponent. As the attacker ranged up alongside, the vessel which got off the first effective broadside at short range, if it were well supported by great intensity of fire for a few minutes, generally won the battle. And intensity of fire, when the range is short, must have great effect in the future. But it seems likely that we may now have one new feature regarding this part of naval duels. In former times, when after some time spent in long-range firing, the vessels were placed alongside one another, and a furious battle with the guns was begun, there was rarely any separation of the combatants. But now when it seems certain that ships will be kept in tolerably rapid motion during combat, and often range alongside when moving in nearly opposite directions, a thing which rarely or never happened formerly, they may be close to each other for a very short time only. During this time, as great an intensity of fire as possible must be maintained from all the guns. A ship's company well trained in executing what a study of tactics indicates they may have to perform may obtain great advantages.

After ships have met bow to bow, and if they pass without either being sunk, it is clearly best to jam the helm hard over at once so as to be bows-on in a second encounter. A vessel which steers on or puts her helm only part way over, may be taken at a disadvantage by one which does put her helm hard over, and thus this is to be recommended. If in this manœuvre a vessel desiring to use her guns rather than ram, sees, when the enemy is abeam, that the enemy is not so far around, she might ease her helm and fire the guns. But there appears to be no resort as against a vessel determined to use the ram, except the ram. We may try to stop her with guns, but should never relinquish the power to meet her bow to bow; and this power will be relinquished, the enemy's bow being towards us, when he is a little more than two tactical diameters astern of us, or is four-fifths tactical diameter broad on the bow.*

---

*It is here and elsewhere assumed that the speeds and tactical diameters of the ships considered are equal.

The study of the tactics of fleets, besides an examination of the possible variations of the angles of presentment between each ship of one side and all of the others, includes that of the grand tactics of fleets, the science of being stronger at the decisive point in battle. The old close-hauled line ahead of sailing ships, which rested upon the facts that ships were easily managed when so disposed, and that the arcs of train of the guns were 3 points on each broadside, was evolved in the great Dutch-English wars of the seventeenth century. And when this line of battle had been once mutually agreed upon, there seems to have arisen in the minds of naval officers a feeling that they must draw their line up and attack the enemy, each ship her opposite. The unfortunate Byng, at Minorca, in 1756, is said to have withdrawn one of his ships from the line in order that the number should be equal that of the enemy.*

This pedantry was overthrown by Rodney and Nelson at the close of the seventeenth century, after having been adhered to by all but the best admirals for a hundred years. This part of naval tactics—the part, so to speak, which is concerned with handling the line of battle in the presence of the enemy—has not been greatly changed by the introduction of steam and rifled guns. Nelson's order of battle at Trafalgar consisted in throwing his second in command with a sufficient force upon the rear of the allied fleet, while he, with the ships which were left, prevented his being disturbed. His celebrated memorandum relating to this affair may be applied to a fleet of steamers by changing a few words. And Collingwood's order of battle of March 23, 1808,† needs only a very few unimportant changes to make it similarly applicable.

But the line of battle, as distinct from the order of battle—from the motions of the line of battle in presence of the enemy‡—has changed entirely in the last thirty years. The line of battle must be so formed as to enable us to maintain suitable angles of presentment and range and to prevent the enemy from doing the same, and this depends solely upon the tactical features of our ships. So far as advantages with the gun go, it is clear that fleets should approach the enemy in "line"; in a line at right angles to the direction in which the enemy is seen. The line might be double sometimes, but it is difficult to see any clear advantage in this in the general case.

The advantage of the line over the column is that the ships are all well up, and able to use their guns to advantage. It is a formation possessing greater concentration, so far as the gun is concerned. A column of 10 vessels will be from 1,000 to 2,000 yards long, and when its van is well within the dangerous range, doing good work with its guns, the rear will be able to do little or nothing. Then, when the enemy is within about 3,000 yards of our line, we would bring him broad on the quarter by a simultaneous turn of all the ships through 12 points. This would bring our fleet in bow and quarter line. If now the enemy holds on straight for us, the fleet desiring to make an impression with its guns must be handled in a way similar to that already indicated for single ships. We must successively bring the enemy abeam, on the bow, and ahead, according to his distance from us, and according to whether our guns have disturbed his operations.

---

*Campbell's Lives of the Admirals.

See Life, p. 359.

‡ See Hamley's Operations of War, p. 404.

If, when we have turned through 12 points as above, or at any later moment, the enemy shows a disposition to use his guns rather than rams, the battle must become a series of passages of the fleets by each other, in which, if anything effective is done, much must depend on captains of ships and junior flag-officers. But fleets thus contesting with each other at close quarters must soon fall into confusion, because ships will be disabled; and the battle will become, as has always been the case, a mêlée. It is the office of tactics to gain us some advantage before the mêlée begins, and to place our ships at its beginning with advantage with respect to the ships of the enemy.

VI.

FISH-TORPEDO ARMAMENT.

By Lieutenant J. T. NEWTON, U. S. Navy.

[Hitherto great mystery has surrounded all the details of the fish torpedo of the Whitehead and Schwartzkopff types, the special devices of which have never been patented, and which have been sold presumably under conditions of secrecy to various governments. The general introduction of these torpedoes into all foreign naval services, and the fact that a number of establishments are concerned in their manufacture and improvement, seem to have modified the attitude of secrecy which has so long been maintained. Whatever may be the reason for this, the works of Ledieu and Cadiat, Guillaume, Bienaymé, Hauser, Sleeman, and others, recently published, and for sale by foreign booksellers, make public much definite information concerning the fish torpedo and its installation on shipboard, and furnish the material for this article.—ED.]

The purpose of the article is to call attention to the great importance attached by other nations to fish-torpedo armament, and to offer matter which may have a suggestive value to those who are interested in its application to our new ships. Its scope embraces the systems of distribution on ships and torpedo-boats of late construction, with descriptions of some discharging apparatus.

DISTRIBUTION OF TORPEDO TUBES.

The following table will give an idea of the schemes of distribution adopted by European countries:

SHIPS.

Nation.	Name.	Class.	Laid down in—	Displacement.	Length.	Tubes.*		
						Stem or bow.†	Side.	Stern or quarter.†
				Tons.	*Feet.*			
Austria	Kronprinzessin Erzherzogin Stephanie.	Coast-defense vessel.	1881	5, 152	279	1 above water, fixed	2 above water, nearly amidships	1 above water, fixed.
	N * * * * *	Protected cruiser.	1887	4, 000	320	1 above water	4 above water	1 above water.
England	Victoria	Battle-ship	1885	10, 470	340	1 above water, fixed	2 under water, 90 feet from stem 2 under water, oblique fire, 80 feet from stem 2 above water, 70 feet from stem 2 above water, 100 feet from stern	
	Impérieuse	Armored cruiser	1881	8, 400	315		2 under water, oblique fire, 60 feet from stem 2 above water, 80 feet from stem 2 above water, 60 feet from stern	
	Orlando	do	1885	5, 600	300		2 under water, oblique fire, 50 feet from stem 2 above water, 75 feet from stem 2 above water, 50 feet from stern	
	Mersey	Protected cruiser.	1883	4, 050	300		2 under water, 70 feet from stem 2 above water, 75 feet from stem 2 above water, 70 feet from stern	Do.
	Archer	Partially protected cruiser.	1885	1, 800	225	1 above water 2 above water, bow		2 above water, quarter.
	Polyphemus	Torpedo-vessel, protected.	1878	2, 640	240	1 under water	4 under water, 60 and 80 feet from stem	
	Rattlesnake	Torpedo-vessel, unprotected	1885	525	200	1 above water	2 above water, 70 feet from stem	
France	Marceau	Battle-ship	1880	10, 600	330	2 above water, bow		Do.
	Jean Bart	Protected cruiser.	1886	4, 162	346	1 above water	2 above water, 115 feet from stern	1 above water.
	Davout	do	1887	3, 027	297	do	2 above water, 140 feet from stern	Do.

	Condor	Torpedo-vessel, protected.	1882	1,280	223	2 above water, each side of stem; arc of 20° train.		Do.
Germany	Oldenburg	Battle-ship	1883	5,200	249	1 under water	2 under water, 70 feet from stern	1 under water.
	Irene	Protected cruiser.	1886	4,400	308	1 under water, below ram.		
	Blitz	Dispatch and torpedo vessel.	[Launched in 1882.]	1,382	245	do		
Italy	Andrea Doria	Battle-ship	1883	11,000	328	2 under water	2 above water, 75 feet from stem	1 above water.
	Italia	do	1877	15,360	400		2 above water, 158 feet from stem. 2 above water, 129 feet from stern	
	Etna	Protected cruiser.	1883	3,530	283	1 under water	2 above water	Do.
Russia	Emperor Nicholas.	Battle-ship	1886	8,440	327	1 above water, stem, fixed. 2 above water, bow		1 above water, stern, fixed. 2 above water, quarter.
	Alexander II	do	1884	8,400	327	2 above water, bow, fixed.	2 above water, nearly amidships	1 above water, fixed.
	Gangoot	do	1889	6,600	300	2 above water, bow	4 above water, nearly amidships	Do.
	Pamyat Azova	Armored cruiser.	1886	6,277	377	do		Do.

---

*Under-water tubes are 7 to 9 feet below the surface, and always fixed; discharge ahead, astern, or abeam is always implied; when oblique it is so stated. Above-water tubes are always movable except when otherwise stated: the English practice is to place them 7 to 9 feet above the water-line; the Germans place them not higher than 4.9 feet, and the French, from 2.9 to 8.9 feet.

†Stem or stern tubes are always implied; when bow or quarter are meant, it is so stated.

From the above it will be seen that the Austrian ships are equipped with above-water tubes for stem, stern, and side discharge.

The English ships, with the exception of the *Polyphemus*, have their stem tubes above water, and are not generally armed with stern tubes. Their side above-water tubes are mounted on training carriages one-third to one-fourth the length of the ship from the stem or stern. The under-water tubes are always fixed, for beam or oblique forward fire, one-fourth to one-third the length of the ship from the stem. Late experiments with the submerged tube in vessels of high speed have given results indicating that many of the difficulties incidental to that system have been overcome.

The French do not use the under-water tube. Their ships are generally equipped with stem and stern discharge, and two training side tubes one-third to one-half the length of the ship from the stern.

The Germans consider torpedo practice from fixed tubes more accurate than from training tubes. Their ships are fitted with few tubes, and those generally under water. The stem tubes are always under water, 9.8 feet (3 metres) below the surface when practicable; otherwise so inclined that the torpedo shall quickly gain that submersion. Side tubes above water are placed as far aft as practicable. Their best height is 4.9 feet for above-water discharge (using the Schwartzkopff torpedo). If placed lower, the projecting spoon may be carried away or bent by the sea. The following are some other conclusions developed by their experiments: At speeds greater than 12 knots the air pressure necessary for accurate discharge from side under-water tubes becomes so great, that the tail of the torpedo is frequently damaged. With twin screws an under-water stern tube is preferred, but if this is impracticable, the above-water tube is substituted. The agitation of the water due to twin screws does not affect the trajectory, but the course of a torpedo through the wake of a single-screw ship is so erratic as to disqualify stern discharge.

The Italian ships are equipped with noticeably few tubes. The stem tubes are placed under water, the side and stern tubes above water. Owing to the recent success of a side under-water tube invented by Mr. Whitehead, ten of their ships are to be fitted with this system of discharge.

All the Russian ships, except the *Peter-Veliki* and one practice craft, are equipped with above-water tubes, at a height not exceeding 6 feet, and set at an angle of from 7 to 10 degrees when practicable.

TORPEDO-BOATS.

Six 83-ton boats of the Schichau type building for the Austrian Government are to be equipped with one stem-tube fitted for air discharge, and one turn-table tube aft fitted for gunpowder discharge.

The sea-going and first-class torpedo-boats proposed or building in England will carry one built-in stem-tube and two torpedo-guns abaft for all-around discharge. The second-class type have two torpedo dischargers aft. Gunpowder discharge is used on all the boats lately built.

The *éclaireur-torpilleur* class building in France includes four of the *Ouragan* type—the *Alarme*, *Aventurier*, *Défi*, and *Téméraire*—equipped with four training tubes, two forward and two aft (these are pivoted to the rail, their inboard ends traversing training arcs); the *Audacieux* and *Agile*, carrying three spoon-tubes mounted on turn-tables—one forward, one amidships, and one aft. The first-class boats have two built-in bow tubes parallel to the keel. Gunpowder discharge is used exclusively.

The German torpedo-boats have two tubes built in the bows parallel to the keel. These boats are all fitted with air impulse for the discharge of the Schwartzkopff torpedo.

The latest Italian sea-going boats are equipped with one built-in stem tube and two turn-table tubes abaft. The first-class boats carry one built-in stem tube and one turn-table tube abaft. The stem tube of both classes is fitted for air impulse, and the turn-table tubes for gunpowder impulse.

The 138-foot boat building for the United States is to have two built-in bow tubes parallel to the keel and one torpedo gun aft.

TORPEDO DISCHARGE.

Compressed air and gunpowder are the discharging agents used, the former only for under-water discharge, and either for above water, though gunpowder impulse is becoming the more prevalent in late constructions.

The table following contains some data concerning the Whitehead and Schwartzkopff and Howell torpedoes:

Nation.	Maker.	Material.	Length.	Diameter	Weight.	Speed for 400 yards.	Impulse.
			Feet.	*Inches.*	*Pounds.*	*Knots.*	
Austria*	Whitehead	Steel	16.4	15.75	961	23.5	Air.
England	Domestic manufacture.	do	....	....	....	....	Air and gunpowder.
France	Whitehead	do	18.9	14.9	880	28.5	Gunpowder.
	do	do	14.5	14	598	28	
Germany	Schwartzkopff	Phosphor-bronze	15.5	14	605	28	Air impulse.
Italy	do	do	15.5	14	605	28.5	Air and gunpowder.
	do	do	16.5	17.7	1,144	30	
	Whitehead	Steel	16.4	17.7	....	....	
	do	do	15.4	13.9	....	....	
Russia	do	do	....	15	....	....	Air and gunpowder.
	do	Bronze	....	15	....	....	
	Schwartzkopff	Phosphor-bronze	15.4	15	....	....	
	Domestic manufacture.	Steel	....	15	....	....	
	do	Steel and bronze	....	15	....	....	
Spain	Schwartzkopff	Phosphor-bronze	15	14	605	28	Air impulse.
			16.5	17.7	1,144	28	
United States†	Howell	Spun brass	9	14.2	410	22.5‡	

* It is stated on good authority that the Austrian Government is experimenting with different discharging apparatus and powders with a view to the adoption of gunpowder in place of air discharge.

† The method of discharge to be applied to the tubes of the United States ships building for the ejection of the Howell torpedo has not yet been decided on.

‡ Minimum guarantee.

It is noteworthy that nations using only the Schwartzkopff phosphor-bronze torpedoes employ air impulse altogether, while with the steel torpedoes either impulse is used for above-water discharge.

The tubes of Russian ships are fitted both for air and gunpowder impulse.

Sometimes the air for discharge is supplied by an air cartridge, which fits in the torpedo tube. The cartridges used by the Spaniards during the manœuvres of their flotilla of torpedo-boats gave entire satisfaction. They were charged to 4 or 4½ atmospheres. An air cartridge invented by Mr. Whitehead, charged to three atmospheres and occupying one-third the length of the tube, is also reported to have given good results. But generally the air is supplied by an accumulator. The following is a description of an air-discharge tube carrying an accumulator:

FRENCH AIR DISCHARGE CARRIAGE FOR 14.4-FOOT TORPEDOES.

(Plate I, Figs. 1, 2, 3, 4, 5, 6, 7, 8.)

The breech of the tube is closed by a hinged door. This is the only particular in which it differs from that supplied by Mr. Whitehead to England, Germany, and Portugal, the tubes furnished those countries being closed with a screw plug having an interrupted thread.

The launching tube A, Fig. 1, is of steel .59 inch thick. The hinged door *a*, closing the breech, is set up by four bolts *b*, Fig. 2. Air tightness is secured by a rubber packing countersunk in the door *a*. The upper interior generatrix of the tube is grooved to receive a projection on the tail which guides the torpedo.

The carriage B, Figs. 1, 2, consists of two iron brackets .78 inch thick, joined by transoms of the same metal.

The trunnions of the launching tube rest on bronze trunnion seats *d*, Fig. 1, fixed to the carriage.

Weight of tube and carriage	pounds..	2, 090
Interior diameter of tube	inches..	14
Exterior diameter of tube	do....	15. 3
Length of tube	feet..	15. 1

The accumulator, Fig. 1, consists of ten steel tubes arranged in three rows.

Interior diameter of accumulator tubes	inches..	2. 99
Thickness of accumulator tubes	do....	. 188

The lower and middle rows have four tubes each. The upper row has only two tubes, and between these, passes the copper pipe D, 1.96 inch interior diameter, which conducts the air of the accumulator to the launching tube. The pipe from the compressor screws on the nozzle *f*.

The upper tubes are shorter and the lower ones longer than those of the middle row. All the tubes are screwed in a bronze junction box *e* strengthened with exterior ribs and interior bulk-heads.

Total volume of accumulator, 3.53 cubic feet.

Plate 1.

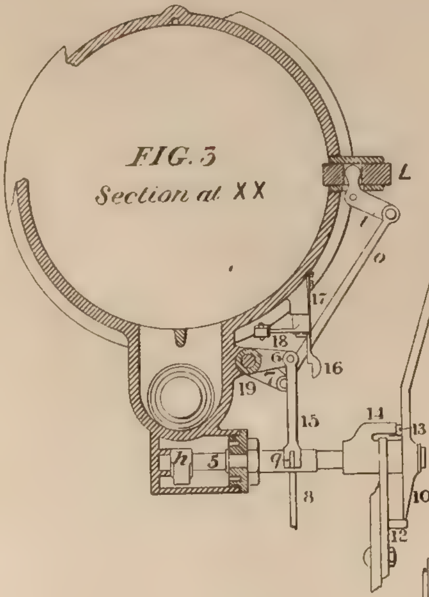


FIG. 3

Section at XX

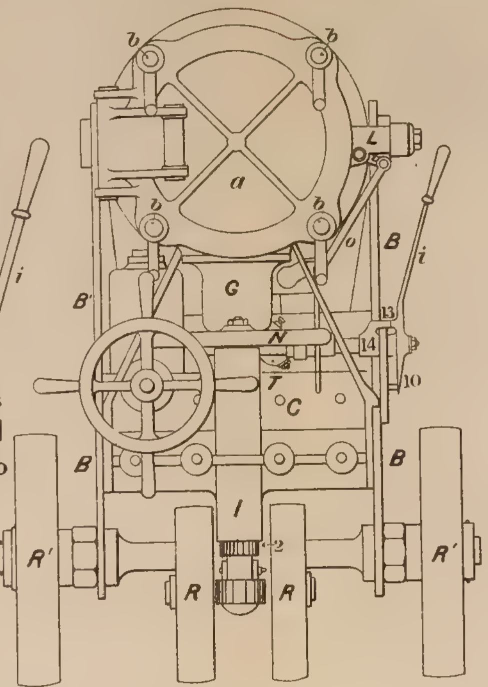


FIG. 2

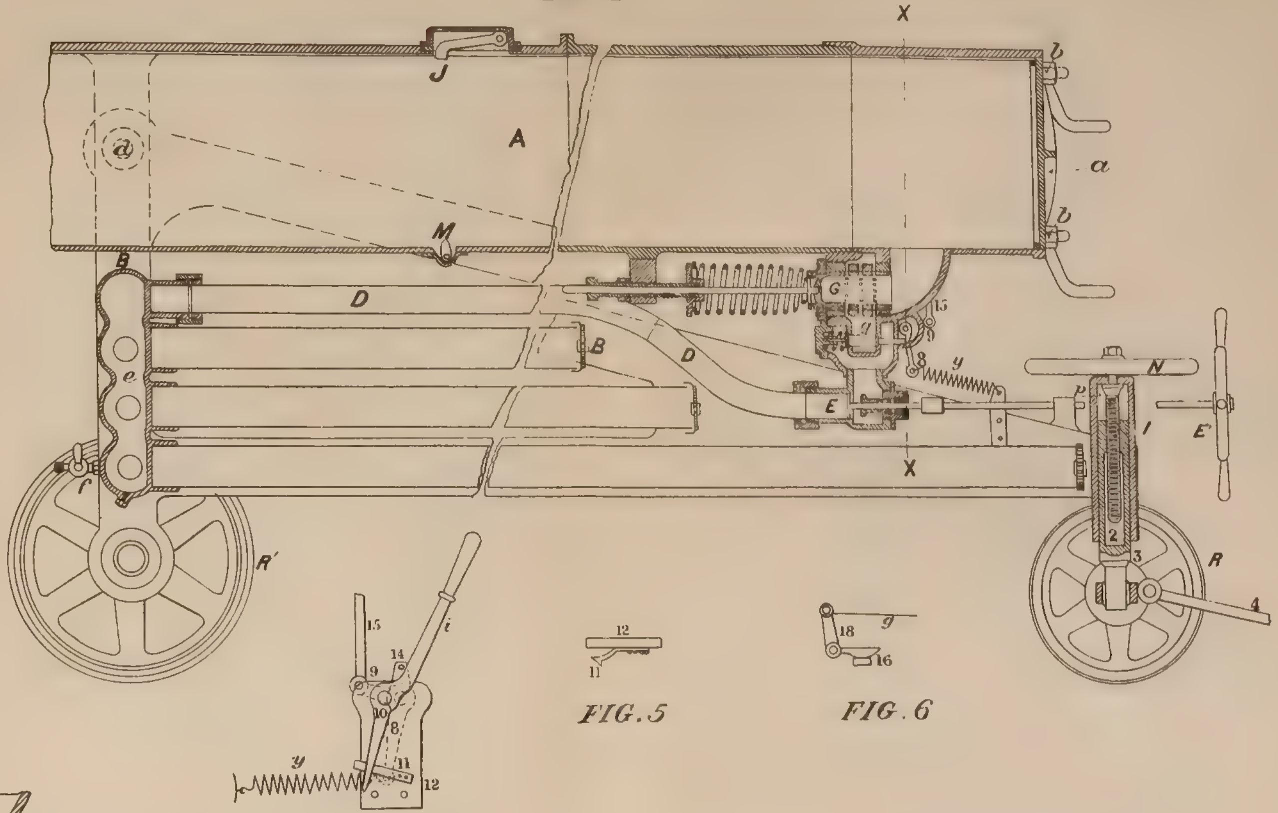


FIG. 1

FIG. 4

FIG. 5

FIG. 6

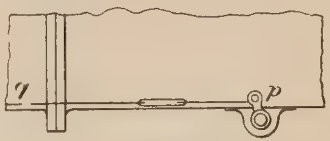


FIG. 7

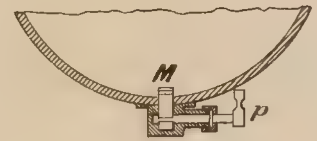


FIG. 8

The stop valve E is worked by means of a wheel E′, Fig. 1.

The pressure regulator G has three rows of holes. The oil cup T Fig. 2 is on one side and below.

The method of closing the launching valve is as follows: On the axis 5 are keyed two cranks, 8 and 9, Figs. 1 and 3. In its normal position 8 is vertical, being held in that position by a powerful spring *y*, connected with its lower end and with the carriage. The effect of this spring is to separate the cam *h* from the valve *g*, and consequently to keep *g* closed.

The normal position of crank 9 is horizontal. To it is keyed a vertical rod 15, Fig. 3; the other end of 15 is connected with a lever 6 pivoted at 19. When 6 is pulled down, its extremity is engaged by the notch of a pawl 16. The upper end of 16 is fastened to the tube, and it is held pressed against the lever 6 by means of the flat spring 17. On the axis of the lever 6 is keyed a crank 7 which works the stop bolt by means of the rod *o* and the bell crank *l*.

The axis 5 is supported by a plate 12 bolted to the carriage bracket. It carries an eccentric projection 14. The lever *i* has its axis of oscillation in the plate 12, Figs. 3 and 4, by the side of that of axis 5 and at the same height. On the lever *i* is a button 13, which rests before launching against the projection 14. Besides, this lever has a lower arm 10, which takes against a flat spring 11, Figs. 4 and 5, and keeps the button 13 in contact with 14.

When the lever *i* is sharply pulled to the rear for launching, the spring *y* is elongated, the axis 5 is turned in the direction for opening the launching valve, and the stop bolt L is withdrawn. Continuing the movement, the button 13 passes over and clears the button 14. When the ejection takes place the bolt L is clear of the torpedo, the lever 6 is caught by the pawl 16, and the valve *g* remains open. The lever *i* may then be let go; it falls below the axis of oscillation.

When the lower vertical frame of the torpedo tail strikes the lever M, Fig. 1, it is carried forward, and at the same time the crank *p*, Fig. 7, and with it the rod *q*, Fig. 7. This motion is transmitted by a bell-crank 18, Figs. 3 and 6, one arm of which pushes back the pawl 16 from the lever 6, which allows the spring *y* to close the launching valve, and the whole system to resume its normal condition.

The lever *i* is revolved to its launching position by turning it in the direction of its first movement until 10 is engaged behind the projection of spring 11, Fig. 4.

The tube and carriage are rigidly connected. Elevation is given by means of the elevating screw *p*, Fig. 1. The box of screw *p* is cylindrical; it is joined to the axle of the rear wheels. By turning the screw *p*, carriage and tube revolve around the front axle.

On the side of the axle of the rear wheels R is a projection 3 on which the lever 4 is shipped. By means of lever 4 the wheels R and the axle are turned around the axis of the screw *p*, as required in manœuvring the carriage.

The automatic action of the valve *g* is very satisfactory; there is no useless expenditure of air. During experiments the accumulator has furnished sufficient air for nine consecutive ejections at a pressure of 1.1 atmospheres.

The large ships are equipped with accumulators separate from their carriages. By means of this arrangement the shock of recoil to which the attached accumulators are subject is obviated.

These carriages are connected with the fighting bolt in the lower port sill by means of a hollow rod more than 6.5 feet long. Below the fighting bolt the air stop valve is fixed to the ship's side. This valve is connected with the launching carriage by a very thick rubber hose 8.2 feet long, which permits the tube to be trained through an arc of 100°.

GUNPOWDER DISCHARGE OF THE WHITEHEAD (FRENCH SYSTEM).

In 1879 experiments were begun in France for the purpose of determining the value of gunpowder as compared with air for ejecting the Whitehead from above water tubes. Nineteen-foot and fourteen-foot torpedoes equipped for action were used. These experiments demonstrated the applicability of gunpowder to torpedo discharge with safety, and in July, 1882, its substitution for air was ordered.

The gunpowder tube occupies less space, weighs less, and requires simpler mechanism. This last advantage is of special value with training tubes, which in some of the latest torpedo-boats are replacing the built-in bow tubes, thereby allowing the boiler compartment bulkhead to be carried further forward. On the other hand, the discharge pressure is not so uniform, and the tube must be thoroughly sponged and cleaned after each ejection. This defect, however, can not be considered a serious objection to its use in torpedo-boat tubes, as from 8 to 16 minutes, depending on the state of the sea, are required to reload after discharge, so that in any case the operation of loading would have to be performed out of range of an enemy's fire.

The French employ two types, the spoon tube and the tube without spoon.

The spoon tube projects half the length of the torpedo outside the ship. They have found that the practice is good when the tube is placed as high as 8.2 feet above the water-line. The torpedo is ejected with the tube horizontal and falls flat on the water in prolongation of the axis of the tube. A roll of 5 or 6 degrees does not affect the accuracy of its trajectory.

The tube without spoon barely projects beyond the ship's side, but this advantage does not compensate for the irregular action of the torpedo, which enters the water at an angle increasing with the height of the tube, thereby causing a lateral deflection which is also affected by the roll, the speed of the ship, and the velocity of discharge.

FRENCH LAUNCHING-TUBE WITH SPOON.

(Plate II, Figs. 1, 2, 3, 4, 5, 6.)

This is one of the types of tubes used for the above-water discharge of torpedoes with gunpowder.

The cylindrical part, Fig. 1, is a short bronze tube cast in one piece. Its dimensions are: Length, 9 feet 9 inches; diameter, 14 inches; thickness of metal, .39 inch; weight, 924 pounds.*

The spoon C, Figs. 2 and 4, is of bronze and can be removed. It is joined to the tube as shown in Figs. 1, 2, 3, and is locked by a screw V on top of the tube. In the later tubes there are two other screws at the extremities of a horizontal diameter. Sometimes the spoon C is prolonged by another lip, connected as shown.

A T-groove is cut in the upper generatrix of the tube and lips. A T fixed to the air flask at the centre of gravity of the torpedo slides in this groove and serves to guide and support the torpedo. The length of the spoon is such that when the T has passed the end of the T-groove, the tail of the torpedo is within a few centimetres of being clear of the tube, and the torpedo falls flat, thereby avoiding the initial dive and consequent deviations.

The tube is held in battery by a fighting bolt. At the breech there are two hooks on each side which take under the training circle and prevent the tube from tilting when the T of the torpedo reaches the end of the spoon.

There is no carriage. The tube rests on the trucks *p* and G, which are fastened to it. The training trucks G turn on the rear circle and the front trucks *p* slide on the front circle.

The elevating mechanism consists of two vertical cogged pieces B, which engage pinions provided with ratchet-wheels E, mounted on the same axis.

A hinged door P, opening downward closes the breech. It is set up by nuts *e*, *e′*. An iron scoop is fitted to the breech to facilitate the insertion of the torpedo.

---

* The latest tubes manufactured by the Société Anonyme des Anciens Établissements, Cail, and the Ateliers de la Loire are of steel. The former manufactory produces tubes of .3152 inch thickness, the latter manufactures tubes .2364 inch to .197 inch in thickness.

The tubes for one of the *Ouragan* type of torpedo boats are to be fitted with chrome-steel shields, which are semicircular in shape and extend over the whole length of the tube and spoon. The shield is held in place by three bands placed equidistantly on the tube. There are lugs riveted to the underside of the shield, three for each band. By means of these lugs and corresponding ones on the bands, the shield is supported at a distance of about 2½ inches from the tube. The shield is about .1576 inch thick, with a light steel angle riveted to the edges longitudinally and half-round steel battens at each end. It is made up of three pieces, the joints being perpendicular to the axis of the tube and flush riveted. A hole is cut in the shield just above the starting-bolt box on the tube, so as to permit access to this box. It is covered by a plain hinged lid with two turning buttons which hold it in place when closed. Weight of tube, 1,095 pounds; weight of shield, 517 pounds.

The spring r′, of the finger D, which throws back the lever of the torpedo air-throttle, is double. The lid *m* is hinged and is set up by thumbscrews. This arrangement permits easy access to the spring r′, which must be examined after each discharge.

The stop-bolt is placed in the lower generatrix of the tube. By means of a shaft *a* below the tube and perpendicular to its axis, the bolt is simultaneously withdrawn with the closing of the circuit. The lower generatrix is considered the best location for the stop-bolt. When set in the horizontal generatrix, the stop bolt takes against the head of one of the screws for regulating the horizontal rudder, and it may, under the continued action of a ship's vibration, dislocate the screw sufficiently to cause a vertical deflection of the torpedo.

The withdrawal of the stop-bolt and the closing of the electric circuit is effected by the Korn-Pichon circuit closer. The following is a description of its mechanism, which is shown in Fig. 5:

L, stop-bolt with a rectangular slot for the bell-crank lever *ii*.
ii, bell-crank lever, pivoted at *q*.
R, spring compressed between the lower face of bolt L and the plug E.
E, a plug closing lower end of case. It contains holes for the escape of the water which may accumulate in the spring chamber when the tube is washed.
S, a metal projection cast with the lower part of the case of the spring R, has a binding post V fixed to it, and insulated from the surrounding metal by ebonite.
g, a metal piston in the axis of the binding post V and in metallic contact with it, held up by a spring *v*, diminishes the shock of its contact with K′, the end of the lever.
e, *e′* nuts screwed on the binding post V hold together the parts of ebonite and copper composing the binding post. Contact between K′ and *g* takes place only when the bolt L is completely withdrawn from the tube.

CARTRIDGE OF COMPRESSED POWDER.

(Plate II, Fig. 6.)

It is of annular shape, .275 inch thick, and serviceable in all tubes and for both sizes of torpedoes. The layers of powder are subjected to a pressure of 2,130 to 2,270 pounds per square inch of surface.

An order of the French Minister of Marine dated September 23, 1882, fixes the charge at .66 pound for discharging the 19-foot torpedo from a ship at anchor or under way.

GERMAN SPOON TUBE.

This is the invention of Schwartzkopff and is adaptable to air or powder impulse. The spoon consists of a bar which is rigged in and out

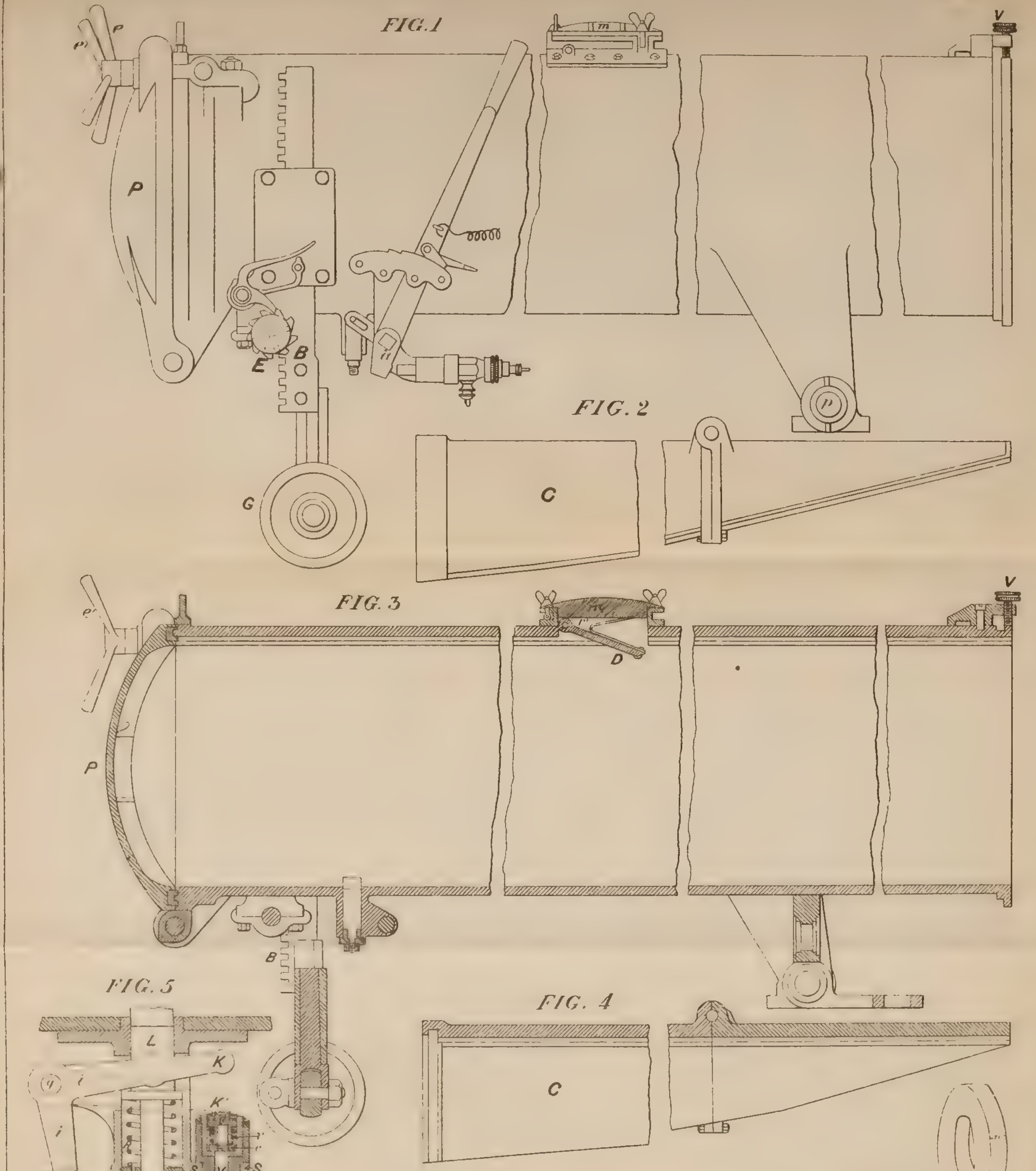


FIG. 1
p
p'
m
V
P
E
B
u
G
p
FIG. 2
C
FIG. 3
e'
m
V
P
D
B
FIG. 5
L
K
q
i
i
K'
S
V
S
E
FIG. 4
C
FIG. 6

Plate II

VAULT

on top of the tube by means of a cogged gearing. This spoon can be rigged out just before discharging the torpedo, and is exposed a shorter time to an enemy's fire than the French spoon.

TORPEDO GUN, CANET SYSTEM.

(Plate III, Figs. 1, 2, 3, 4, 5, 6.)

This discharging apparatus was designed by M. Canet, Ordnance and Torpedo engineer of the Forges et Chantiers de la Méditerranée, and installed on the *Unébi.*

The tube A of bronze consists of two parts, flanged and bolted together. The outer section terminates in a sphere by means of which the tube is coupled with the ship's side and is allowed train or elevation. The breech is closed by an interrupted screw breech plug, which is worked by means of a grip *d*, Fig. 6, and a pinion with an axle *e*, Fig. 6, engaging the toothed sector *e'*

Grooves throughout the upper and lower generatrices of the tube serve as guides for the torpedo.

A stop bolt *c*, Figs. 1 and 2 retains the torpedo in the tube.

The chamber *c* for the cartridge is cut on the front face of B. Lateral holes give outlet to the powder gas against the sides of the tube and not against the tail of the torpedo.

The firing apparatus consists of a hammer *f*, Figs. 2 and 6, carried by a bolt *g*, which is movable up and down in a groove *h*. The hammer has two projections *i*, Fig. 6, which rise on two inclines when *g* is moved up. This movement raises the head of the hammer and compresses the spring *m*, Fig. 2, which is released and works the hammer as soon as the projections *i* of the hammer pass the top of the inclined planes.

The raising of the bolt, and consequently the operation of the hammer, are effected by the following mechanism:

A lever *n*, Fig. 1, revolving about an axis *n'*, and held to the front by a spiral spring *o*, is held by a trigger, fixed by a safety-pin. On the same axis *n'* two lever arms *q* and *r* are mounted, Fig. 1.

When the lever *n*, detached from the trigger *p*, yields to the effort of the spring *o*, the arm *q* pushes the bolt *g* up, and the arm *r* acts on the stop-bolt. The bolt *c* is withdrawn a little before the cap is struck by the hammer.

The trigger *p*, Fig. 1, is worked by the lever *s*, the lower arm of which is held to the rear by the spring *t;* its upper arm rests on the soft iron armature of an electro-magnet. When the current is closed through the electro-magnet the armature is drawn clear of the lever arm, and the lever *S* turns at *k* under the effort of the spring *t*, and through the intermediate action of the rod *v* pushes back the trigger *p*.

The arm of the lever *q*, and consequently the whole system, can be moved only when the breech is completely closed.

To prepare the percussion apparatus engage a lever in the socket *W*, Fig. 6, and turn the axis n'; this works the levers n, q, r. Make sure that the lever s rests on the armature of the electro-magnet, and connect the trigger p with the lever n by means of a safety-pin, which is taken out when the gun is loaded and the torpedo in place.

The tube, if mounted on deck, is supported a little in rear of the middle by trucks, Fig. 4, to which an elevating apparatus is fixed. The tube may also be suspended from the beams, as shown in Fig. 5.

GUNPOWDER DISCHARGE FROM FRENCH TORPEDO-BOATS.

(Plate IV, Figs. 1, 2.)

The fixed tubes are built in the bow parallel to the keel and symmetrically on each side of the central longitudinal plane.

The height of the tube muzzle varies from 0.65 foot to 3.28 feet above the water-line. The inclination is 7 degrees for torpedo-boats of 27 metres which diminishes to about 4 degrees when the bow is raised at high speeds. The inclination is about 4 degrees for other boats and this diminishes to 2 degrees at high speeds. Any unsteadiness or tendency of the torpedo to slip out of the tube due to the vibration of the boat is overcome by brakes, Fig 1, which bear against the forward part of the air flask with a spring pressure of from 220 to 550 pounds. These brakes are set in the tube at 45 degrees on either side of the vertical longitudinal plane.

The following is the arrangement for closing the circuit and withdrawing the stop-bolt: One of the two wires from the cartridge is fastened to the binding post A, Fig 2, common to both tubes, and in metallic contact with the hull and launching tube. The other wire is connected with the insulated binding post *B*. There are two of these binding posts, one for each tube.

The circuit is closed by pulling the rod *o* to the rear. The point *K* of the bell-crank lever *i* comes in contact with the movable piece *p* of the circuit closer, but not until the bolt has been withdrawn. The rod *o* is provided with a small metallic catch, which is engaged by spring pressure against the rear face of the support *k* when the rod *o* has come to the end of its travel, thereby preventing the stop-bolt from re-entering the tube.

DIVERGENT TUBES.

(Plate IV, Fig. 3.)

Some of the torpedo-boats furnished by Yarrow to England and Italy are equipped with the double divergent tubes, gunpowder discharge.

The object is to increase the dangerous space, and in that way to offset the deviations to which the trajectory of the torpedo is liable, and to decrease the target's chances of escape by manœuvring.

A 16-knot ship, 300 feet long, will run her length in eleven seconds. A 28-knot torpedo will traverse 400 yards in twenty-five seconds. As-

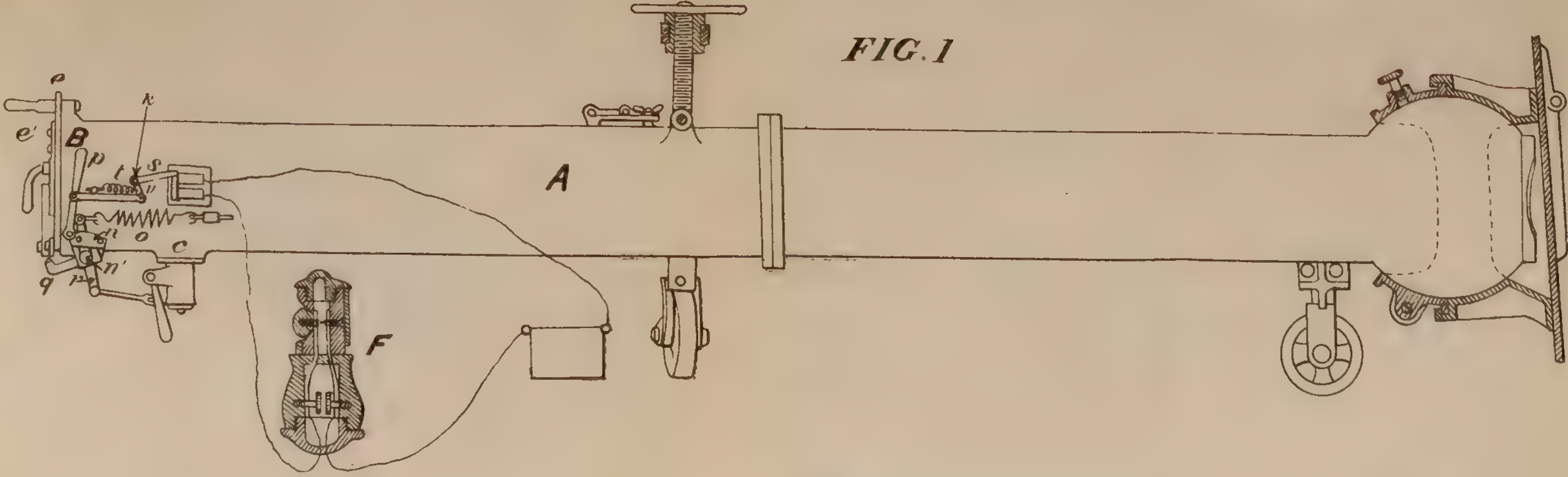


FIG. 1

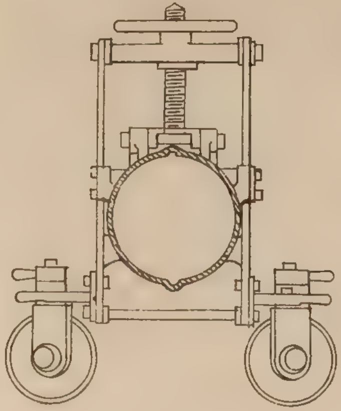


FIG. 4

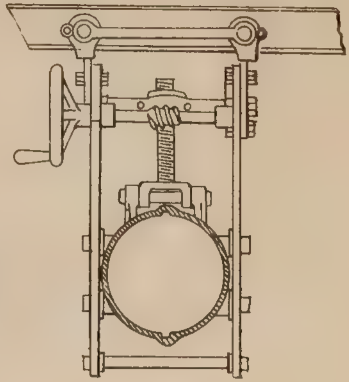


FIG. 5

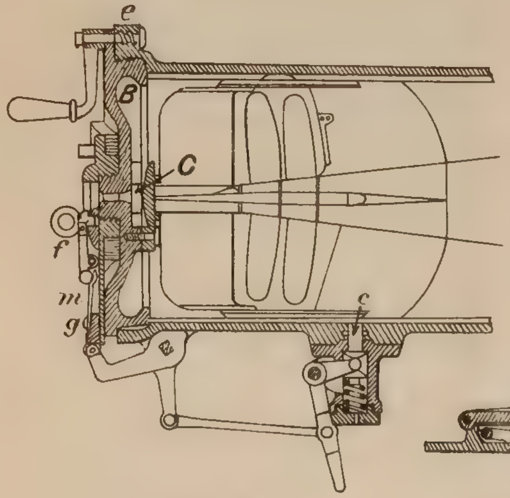


FIG. 2

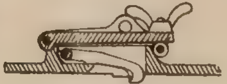


FIG. 3

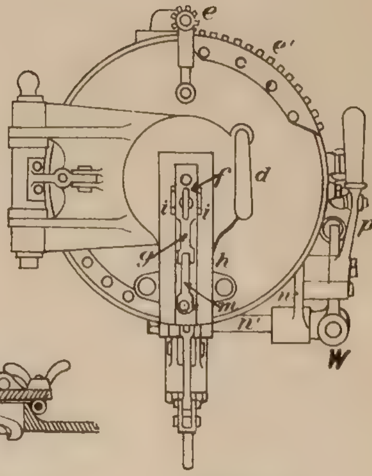


FIG. 6

Plate IV.

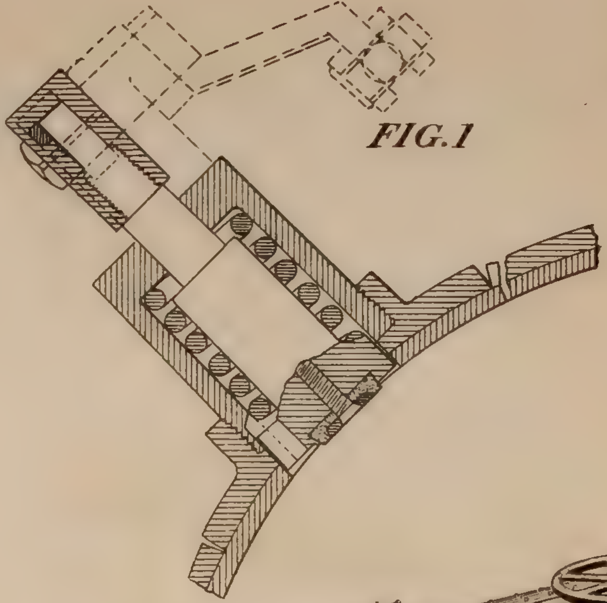


FIG. 1

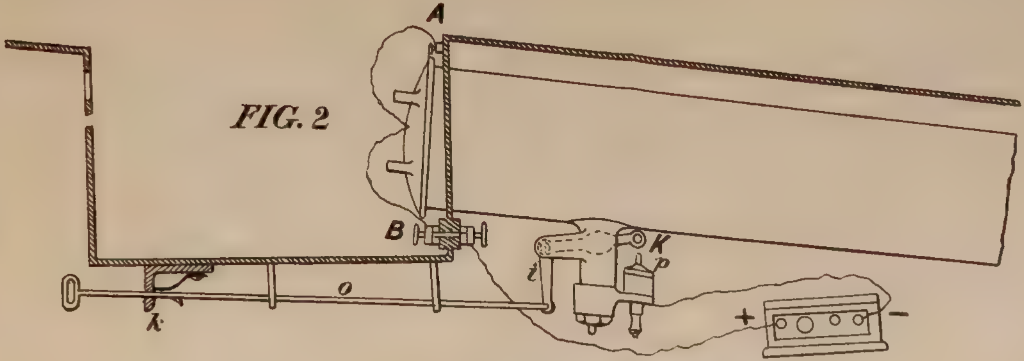


FIG. 2

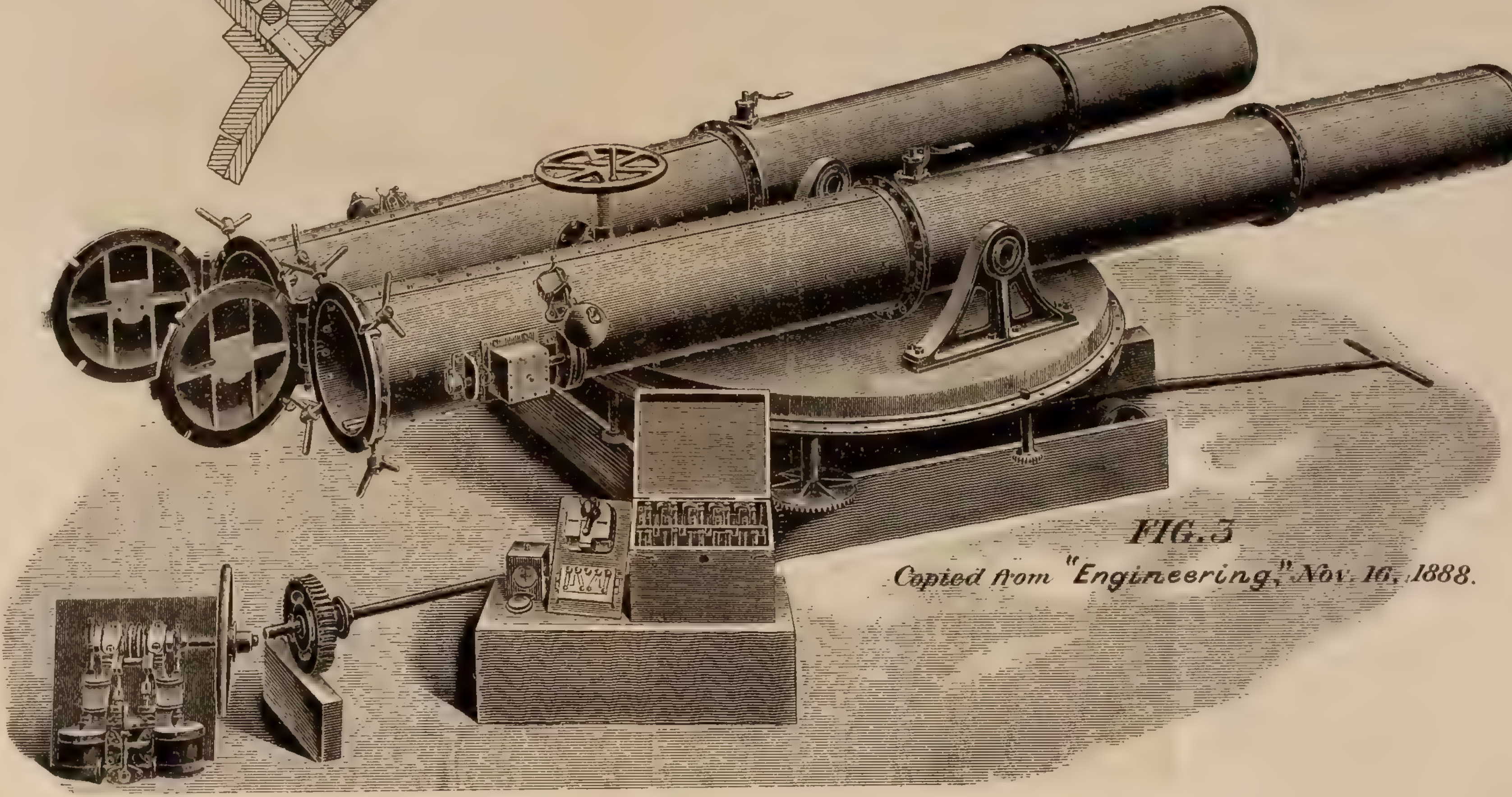
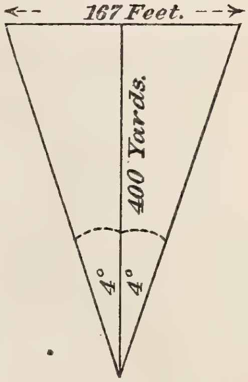


FIG. 3

Copied from "Engineering," Nov. 16, 1888.

suming five minutes to be the time required for a 300-foot ship to make a circle, she will in twenty-five seconds have turned through an arc of 30 degrees, thereby reducing the length of the target to 259 feet, and as she would probably turn from the point of attack the distance to be run by the torpedo would be increased.

With a single tube the target is only 300 feet long. With double divergent tubes, used under the same conditions, the axes of the tubes being inclined to each other at a horizontal angle of 8 degrees, the 300-foot target is exposed to contact while passing through 167 feet. After entering this space the ship is exposed for the first 167 feet of her length to contact with one torpedo, and as the remaining 133 feet pass through this space she is exposed to contact with two torpedoes, and then for 167 feet to contact with one.



The dangerous space is represented by 467 feet, and the above-conditioned ship would be in that space 17.5 seconds if she made a straight course across it.

UNDER-WATER TUBES.

(Plate V, figs. 1, 2.)

The following sketches, which may be considered to embrace the features of under-water discharge, represent the arrangement of the tubes and their appendages on board H. M. S. *Polyphemus*.

The parts of the apparatus are:

A cap (not shown) at the outer end of the tube A or A′, manipulated from the inside by suitable mechanism.

A sluice valve C or C′, to admit water after the insertion of the torpedo and to prevent the entrance of water after discharge.

A drain pipe D or D′.

An air reservoir B or B′.

In Fig. 2, there is additionally a guide bar and shield projecting from the ship's side to prevent the nose of the torpedo from being deflected before the tail has cleared the side.

This function was not satisfactorily performed by the guide bar and shield, and experiments were made with another device on the *Mersey* in the spring of 1887. In this case tapered grooves were cut in the ship's side abaft the tube to allow the torpedo to be carried bodily aft without endangering the tail. At moderate speeds this arrangement gave satisfactory results, but at 18 knots the torpedoes were badly scored and some were broken up.

COMPARISON OF UNDER-WATER AND ABOVE-WATER DISCHARGE.

The right-ahead or the right-astern under-water discharge subjects the torpedo to the least strain, it causes the least deflection to the torpedo, and is the only discharge that has reached a high degree of accuracy from ships. Under-water discharge in general offers protection to the men manipulating and adjusting the torpedo, protection to the tube and torpedo against damage and premature explosion caused by an enemy's fire, immunity to the torpedo from derangement of adjustment caused by striking the surface of the water or by the concussion of neighboring guns. *Per contra*, the tube is fixed and can be pointed only by means of the helm; consequently an enemy knowing its location might under certain conditions be able to avoid its line of fire. In the case of the broadside discharge tube and torpedo are liable to damage by the pressure of passing water, and the latter to damage by contact with the ship's side.

Above-water discharge possesses the following advantages: The tubes can be trained more quickly, and can be readily located anywhere on deck. *Per contra*, tube and torpedo are liable to damage by an enemy's fire, and the latter to premature explosion of its charge or air flask; the height of fall may occasion derangment of adjustment or strain the torpedo, and when the ship is rolling its direction of entrance is uncertain.

Plate V.

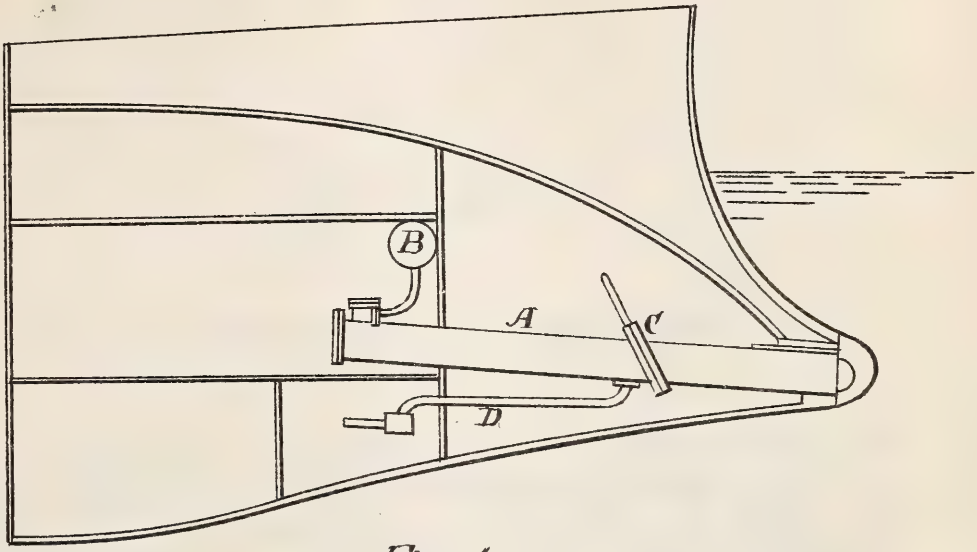


Fig. 1

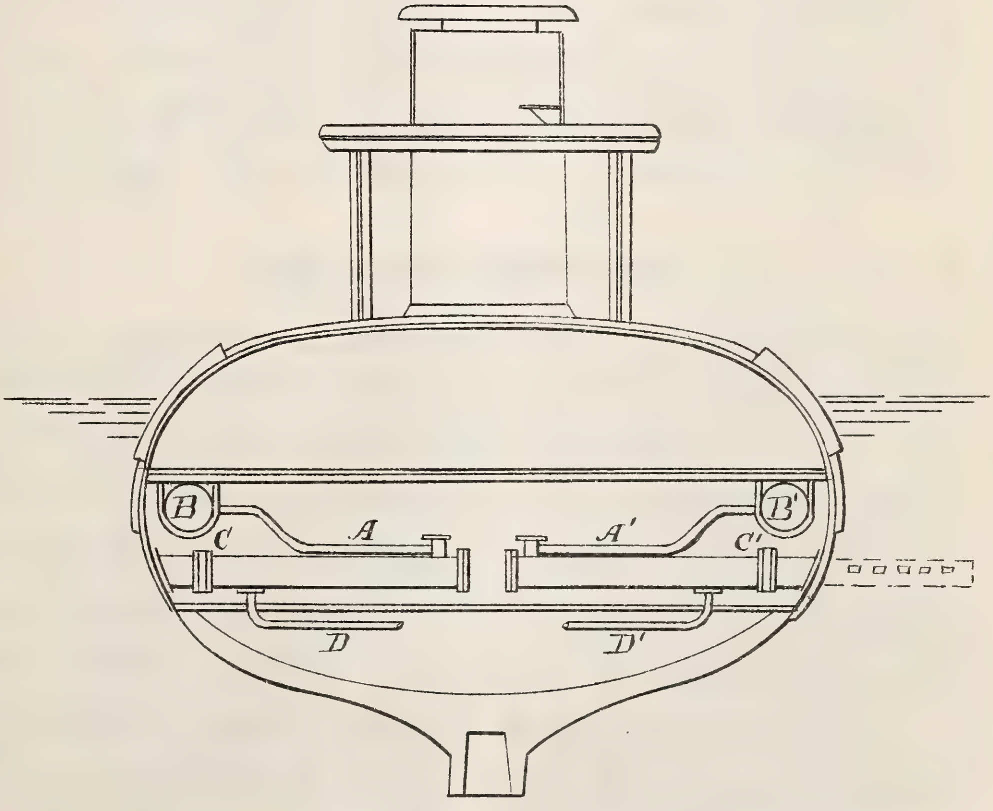


Fig. 2

VII.

PROPULSION.

By Passed Assistant Engineer C. W. Rae, U. S. N.

Since the introduction of the screw propeller, in 1836, no part of the propelling machinery of vessels has advanced so little in efficiency. That efforts have been made and are still making to increase our knowledge of the screw, the transactions of the engineering societies and the columns of the engineering journals bear evidence. The object of this paper is simply to collate this information in order that those so situated as not to have access to the sources from which it is drawn may keep themselves informed of what is doing in this direction. Much that follows is old and has appeared in print before, but in studying the literature of the subject so many references to these older papers are found—especially to those read before the Institution of val Architects—that it is thought best to quote quite freely from n.

THE SCREW PROPELLER.

The screw propeller is an instrument for converting the engine power of a vessel into propulsive effort, which is accomplished by the reaction he water acted upon, and is measured by the weight of water mul- lied by the distance through which it is moved in a unit of time. The ratio of the power transmitted to the screw to this work done constitutes the *efficiency of the propeller*, and the object of all designs is to make this ratio as large as possible. It follows from the above that the screw should be so shaped as to move the whole of the water acted upon in a direction opposite to that of the ship's motion. Moved in any other direction, only the component in the direction of the ship's motion of the force required to move it results in propulsive effort. All screws have a tendency to throw the water off radially as well as axially, and as early as 1843 the Earl of Dundonald patented a propeller with the blades thrown back in order to counteract this tendency.

The following brief description of the best-known screws is taken from Barnaby's Marine Propellers:

"The form of Griffith's screw, which is most in use, is represented in Fig. 1.

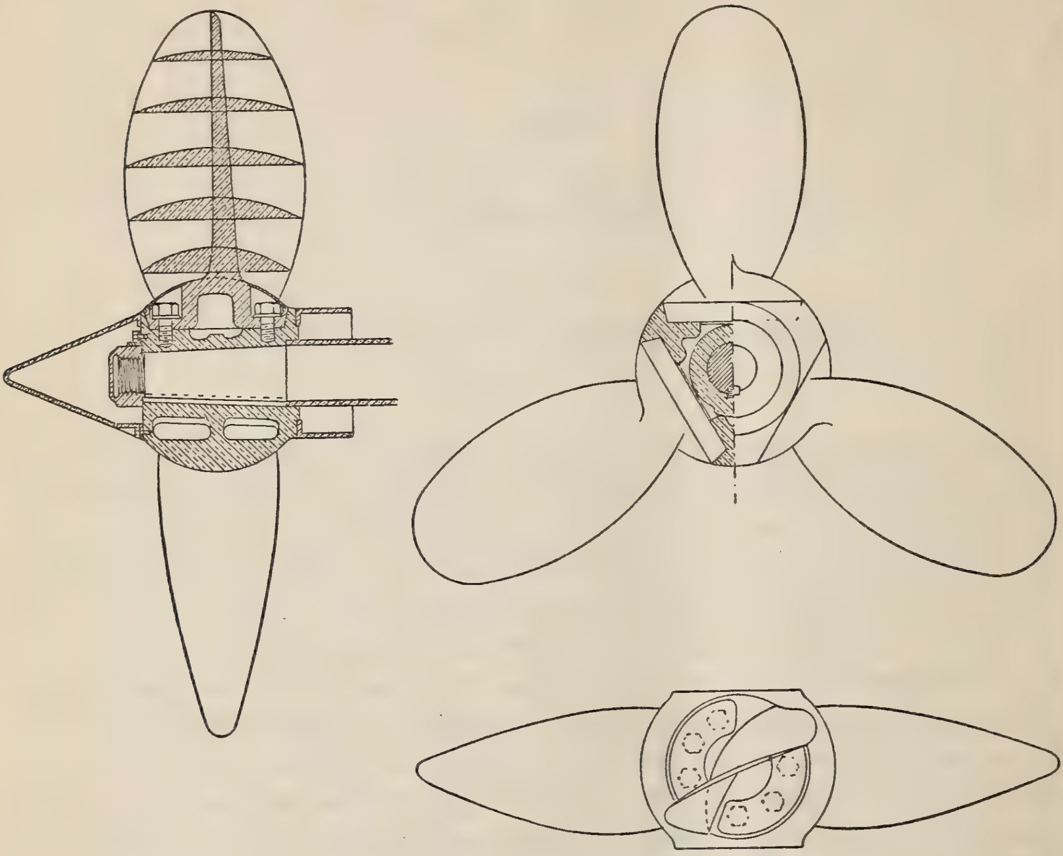
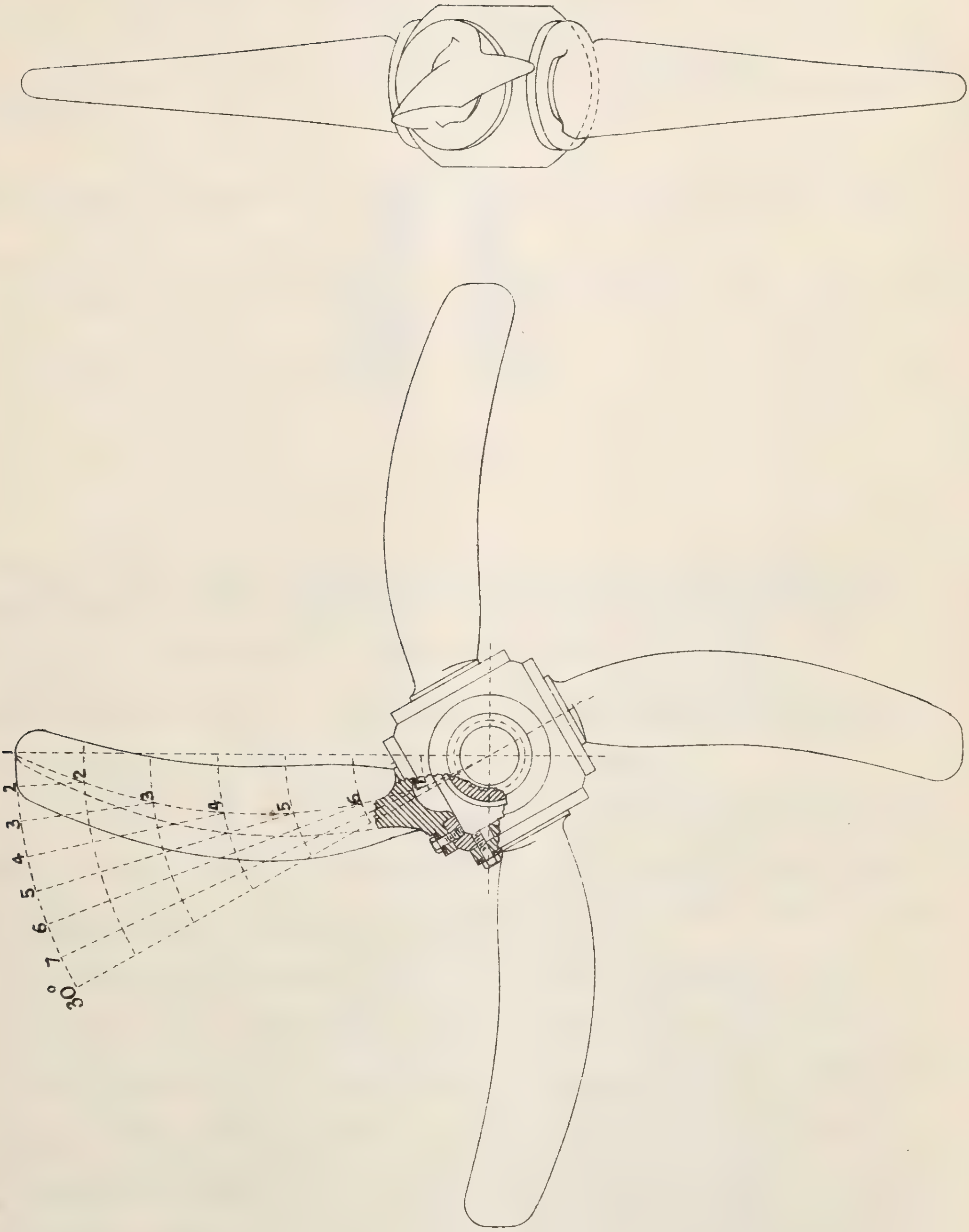


FIG. 1.

"I think the principal feature in his propeller is the large boss, one-fourth the diameter of the propeller, which, while not impairing the efficiency, enables the blades to be fixed in such a manner that the pitch can be readily altered. This is an important consideration, as it is very difficult to fix upon exactly the right pitch in designing a new propeller, and it is extremely convenient to be able to alter the pitch without making a new propeller.

"The Hirsch screw (see Fig. 2). The features of this propeller are that the pitch increases in the direction of its length, and that the propelling surfaces are so formed as to throw the water somewhat toward the axis, with the view of counteracting the centrifugal force. The outline is curved, possibly with the idea of having less edge resistance, because of its cutting through the water more easily than a straight-edged blade. This is a fallacy, because a blade can not cut its way gradually into water when it is wholly immersed.

Fig. 2.



"Mangin's screw (Fig. 3) consists of two narrow screws set behind one another on the screw-shaft, with a space between them. It is supposed not to rotate the water so much as other screws.

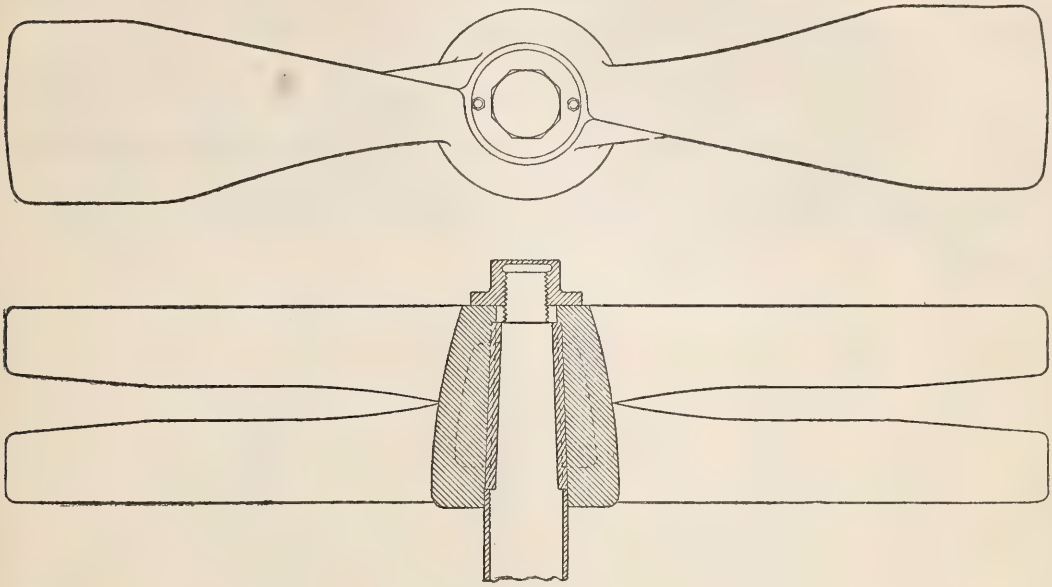


FIG. 3.

"Riggs's screw had a fixed screw or guide blades set behind the revolving screw, with the blade set at the reverse angle, so as to take the rotation out of the water and leave it moving directly astern.

"Rankine and Napier patented a modification of this idea in the form of a twisted rudder, of which the part above the screw-shaft bends in one direction and the part below in the opposite.

"Screws have been tried with the pitch in the centre less than the pitch at the circumference, so as to allow the central part to follow up the water as in a nut—the circumferential part doing the most work—the design being to prevent a centrifugal motion being given to the water by the action of the central part of the screw.

"The Thornycroft torpedo-boat screw, which has been a very successful screw, has an increasing pitch at the middle of the blade, but the pitch gradually becomes uniform toward the roots and towards the tips, the reason being that towards the roots the rotation given to the water is already excessive, and it is consequently not advisable to increase it by increasing the pitch; and towards the tips, if it is attempted to accelerate the water too much, it escapes round the tips to the back of the blade—'short circuits' it in fact. The tip of the blade does very little good, only you must have a tip. The blades are thrown back after the fashion of the Dundonald propeller, but, instead of being straight like his, they are convex on the driving face. The object is to counteract centrifugal force, and as the rotation which produces it is greatest at the root and diminishes towards the tips of the blades, the angle to which the blade is inclined to the axis varies in a similar way.

"We have made a number of experiments at Chiswick with models of propellers which I shall describe more particularly in another lecture, but I may say that this propeller was superior to any tried.

"As, however, it is very important to prevent the propeller breaking the surface of the water, and as the draught of the torpedo-boat is small, it has been found a great improvement to use a smaller propeller with broad blades (Fig. 4), which can be completely immersed, although the older form, with long thin blades, if completely immersed, is slightly superior."

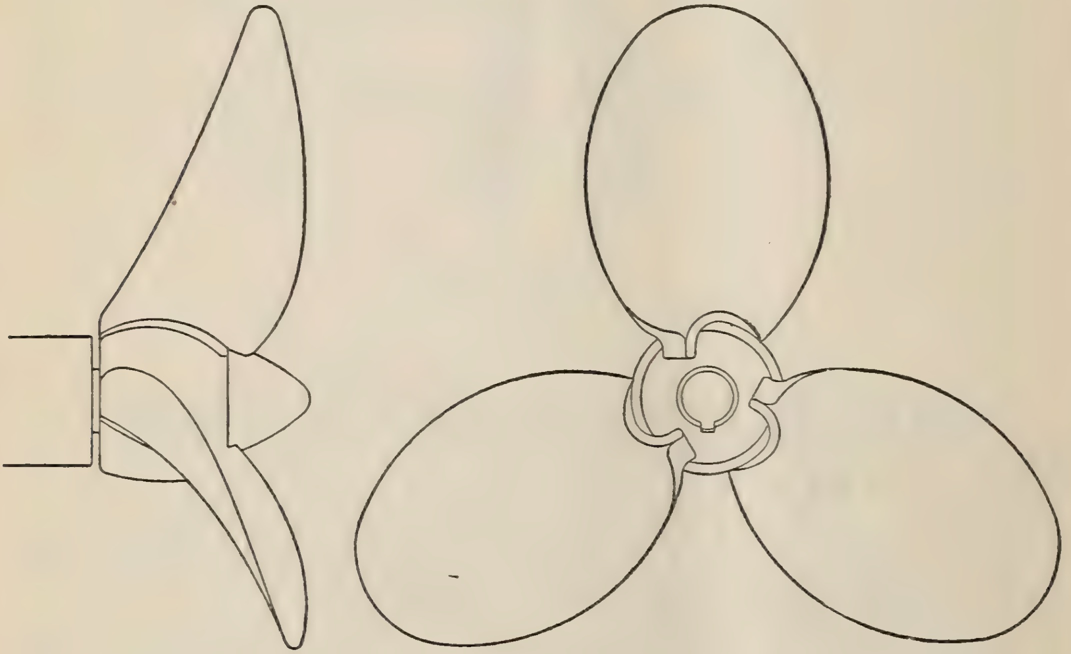


Fig. 4.

There are many devices employed for feathering the blades of propellers, placing them either fore and aft when the ship is under sail alone, or altering the pitch to suit the circumstances when under steam, among the best of which is that patented by Mr. R. R. Bevis. The chief advantages of this device are its simplicity, its non-liability to accident, owing to the fact that the mechanism is contained within the boss of the propeller, and that it is operated from within the ship. The blades are attached to the boss in the usual manner for feathering blades. Around the spindle of the blade is secured a collar carrying an arm, the end of which arm is connected by a bent link to a small cross-head on the end of a rod running through the hollow propeller shaft to such point in the shaft-alley as it is desired to place the operating mechanism. The longitudinal movement of this rod, acting through the link and arm, revolves the blade to the required position. This movement is obtained in the following manner: In the hollow shaft is cut a slot in which works a feather secured to the inboard end of the rod; this feather pro-

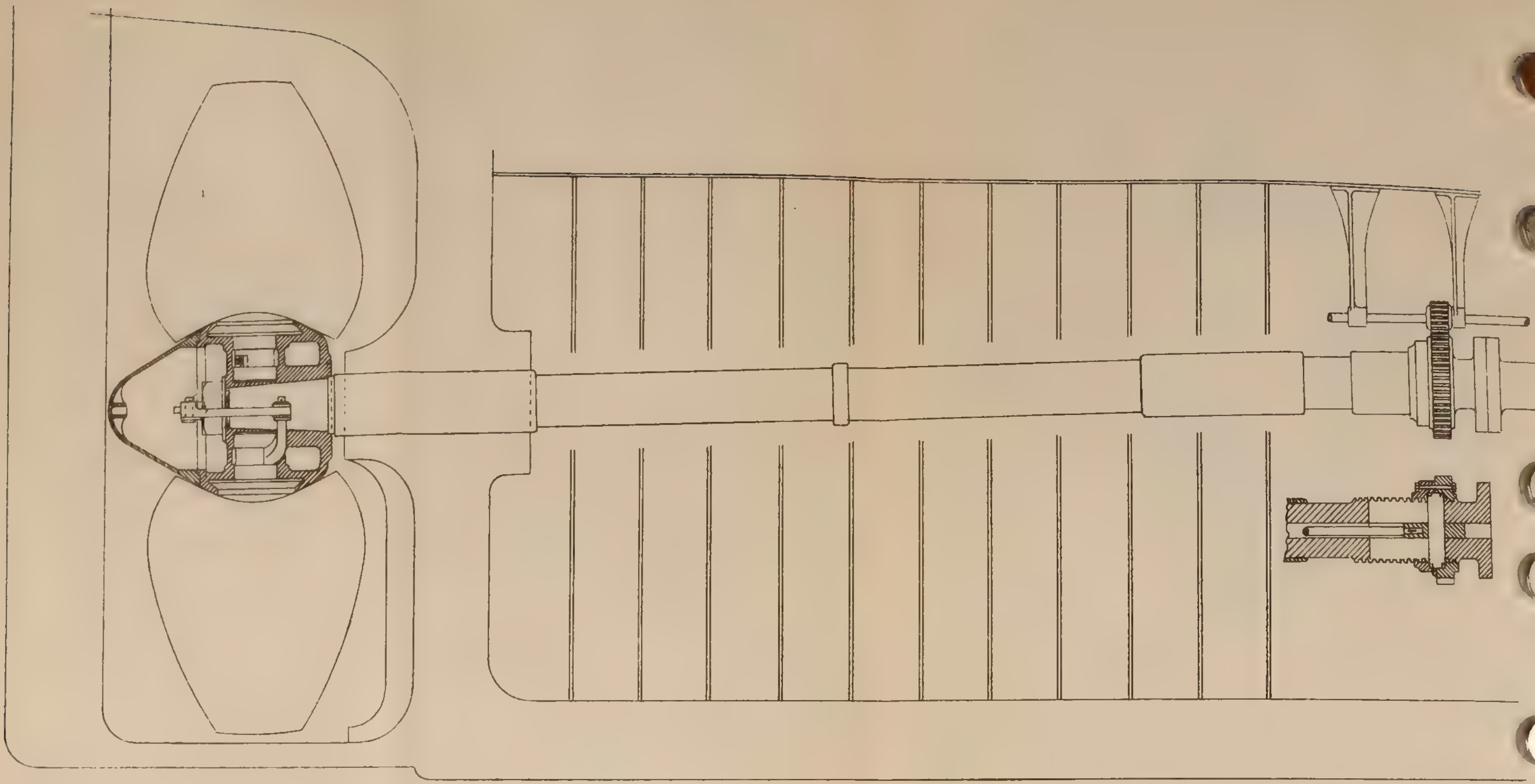
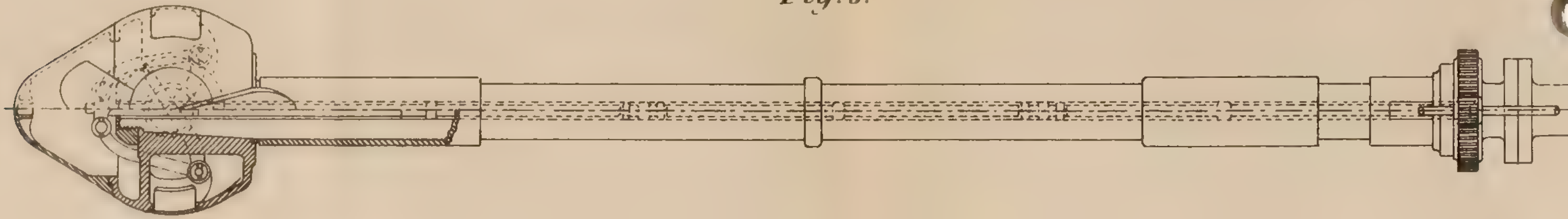


Fig. 5.



jects beyond the shaft on both sides, its ends being embraced by a large nut, on the interior face of which is cut a way to permit of the nut being revolved while giving an axial motion to the feather. The nut works around the shaft, which is provided with the necessary thread. The length of the slot is such as to give sufficient motion to the rod to revolve the blade from its maximum limit of infinite pitch to its minimum limit of the least pitch for which it is designed. Most any mechanism can be employed to move the nut, dependent on its size and the power required to do so. This device has been fitted to many ships in the British navy, and is highly spoken of by British Admiralty officials. (See Fig. 5.)

The screw-propeller, owing to its manner of action, impresses a motion upon the water acted upon which can be resolved into two component motions, the one in the direction of its axis, which is utilized in propelling the vessel, the other in the direction of motion of the screw's disk, which is the rotational component and is an absolute loss in the ordinary propeller.

If this rotational motion can be taken out of the water by a fixed propeller attached to the ship, so proportioned that the water leaves it with a longitudinal motion only, then we have regained as much as is possible of the power expended in giving it that rotary motion.

Of all the devices brought out to accomplish this end the best is the guide-blade propeller of Mr. Thornycroft.

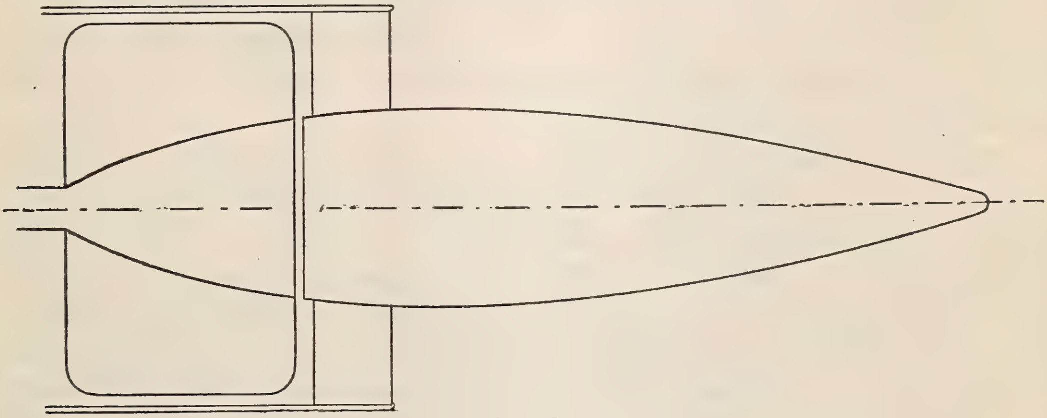


Fig. 6.

This propeller works in a casing or tube, which extends some distance abaft the propeller and contains in its after part the fixed guides. The boss of the propeller increases in diameter from its forward to its after end. The fixed guides also have a boss which in shape is a continuation of the boss of the propeller, the diameter at its forward end being the same as that of the propeller boss at its after end, its greatest diameter being in the plane of the after end of the casing, and from that point gradually decreasing until it ends in a point. By this arrangement the area of the channel through the casing is reduced, and the velocity of the water flowing through it is continually accelerated up to the moment it quits contact with the propelling instrument. The long body, or continuation of the fixed boss, permits the streams of water to reunite without forming eddies.

Mr. Thornycroft has taken out three patents on his guide-blade propeller, the first in 1879, which is practically that described above; the second in 1881, which modifies the first in making the body in two parts, the after part of which is so mounted as to have a motion from side to side after the manner of a rudder; and the third in 1886, which is a device for overcoming the inefficient action of the propeller in going astern. This latest device was proposed by Admiral Selwyn during the discussion on Mr. Thornycroft's paper on guide-blade propellers, in March, 1885, when, in speaking of overcoming their lack of efficiency in going astern, he suggested "deflecting the currents produced by this forward pump." Mr. Thornycroft has accomplished this by a device changing the vessel from a screw propelled one in forward motion into an hydraulically propelled one in backward motion, the engine maintaining a constant direction of revolution.

The device can be readily understood from the figures.

With this arrangement the stern of the boat is constructed in a peculiar manner, the propeller working in a partial tunnel or chamber with a curved movable top. From this chamber are two curved passages leading through the sides of the vessel above water and pointing forward of the beam. The curved top is mounted upon an axis, placed at an angle with the propeller shaft, which also carries the after part of the body, the dividing line of which with the forward part, is at right angles to the axis and inclined to the propeller shaft. This axis is mounted in suitable bearings and is revolved through an arc of 180 degrees by any suitable mechanism.

When in position for ahead motion the curved cover fits snugly in the top of the propeller chamber covering the entrances to the curved passages, and the axis of the after part of the body is in line with the propeller shaft. (See Fig. 7.) For rearward motion the axis carrying the curved cover and the after part of the body is revolved through an angle of 180 degrees. By so doing the entrance to the curved passages are uncovered, the fairway at the rear of the propeller is closed on its under side, and the after part of the body points towards the opening leading to the curved passages. The water after passing the propeller, the propeller still revolving in the same direction, is deflected up and into the curved passages, escaping from their outlets and driving the boat astern as in hydraulically propelled vessels. (See Fig. 8.)

The outlets of the curved passages are provided with valves to regulate the amount of water discharged from the two sides respectively and thereby assist in manœuvring.

Experiment has shown that for maximum efficiency the propeller must nearly fill the tube; that is, that the clearance must be only enough to insure proper mechanical working of the apparatus.

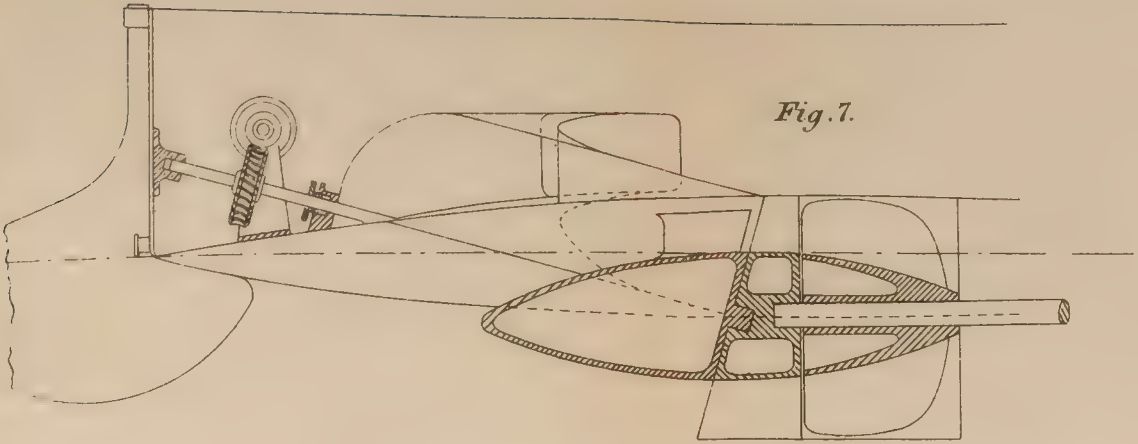


Fig. 7.

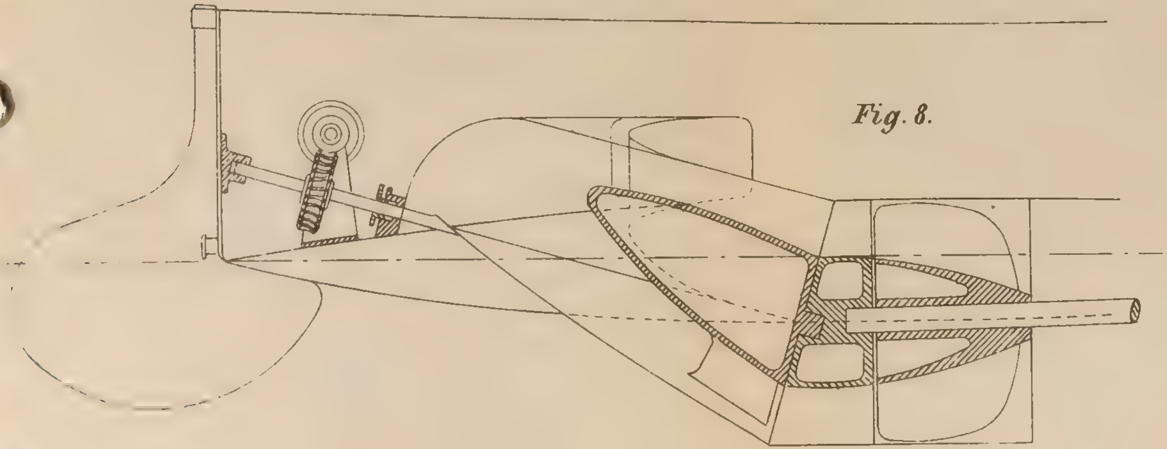


Fig. 8.

The device of permitting the propeller to work in a tunnel, the top of which is above water, but the sides and ends of which are submerged, appears to have given excellent results in some light-draught boats built by Mr. Thornycroft.

By this means a propeller of greater diameter than the draught of the boat can be used. As soon as the propeller begins to revolve the air is driven out of the tunnel and its place supplied by water, permitting the propeller to work wholly submerged. The work done in raising this water to the height of the crown of the tunnel above the level of the water outside is restored by its falling from that height back to its normal level.

Boats fitted with guide-blade propellers working in tunnels have been very efficient in light-draught vessels for river work.

DIAMETER.

It was formerly supposed that as large a diameter as possible was advantageous, and the draught of the ship less the clearance at the bottom and the immersion of the upper edge at the top gave at once that dimension. Frictional resistance of the blade, which will be spoken of later on, has, however, placed a limit upon the diameter.

From tables containing data of the trials of three large transatlantic steamers, the *Alpha*, *Beta*, and *Gamma*, showing the comparative merits of large and small screws on the same ship under similar conditions of displacement, cleanness of bottom, and weather, taken from a paper by Arthur J. Maginnis, esq., and published in the Transactions of the Institution of Naval Architects, 1879, Vol. XX, and also in Navy Scientific Papers, No. 12, are drawn the following conclusions:

"By these results it will be seen that propellers of small diameter have in each case proved the most economical and effective; that on the steam-ship *Alpha* having given a reduction of 3 per cent. slip and 111 tons of coal on round voyage, and an increase of .3 knot per hour in speed; that on the steam-ship *Beta* gave a reduction of 2.4 per cent. slip and 63 tons of coal on round voyage, and an increase of half a knot per hour in speed; that on the steam-ship *Gamma* gave a reduction of 2 per cent. slip and 152 tons of coal on round voyage, and an increase of half a knot per hour in speed."

Mr. Maginnis, in the same article, tabulates the data bearing on the subject from the trials of H. M. S. *Iris*, and says:

"In the case of H. M. S. *Iris*, the particulars are taken from the reports published in the Times. By these it will be seen that the smaller propellers prove much superior, having driven the vessel at a speed of 18½ knots per hour, which the larger propellers were totally unable to do. The smaller propellers also gave a speed of 16½ knots (the maximum of the large) with about two-thirds of the indicated horse-power. The consumption on the trial has unfortunately not been published, but if we assume it to be 2 pounds per indicated horse-power, the saving of fuel effected at this speed would be about 42 cwt. per hour, or 50 tons per day, and at a speed of 12 knots about 13 cwt. per hour, or 16 tons per day.

"From the foregoing it is evident that the small diameters give the best results, and also (excepting in the case of the *Iris*) that the existing pitches are a little too coarse, for, if the speed of piston will allow it, a slightly reduced and more uniform pitch will be found advantageous in many ways, as was found to be the case with the *Gamma*, the piston speed having been raised from 460 to 520 feet per minute by the smaller propeller, and since the increase the engineers have reported the general working of the machinery to be greatly improved."

PITCH, SLIP, AND AREA.

The Pitch of a screw is the length, measured on the axis, of one convolution of the thread or the distance the screw would travel axially in one revolution if working in a solid nut.

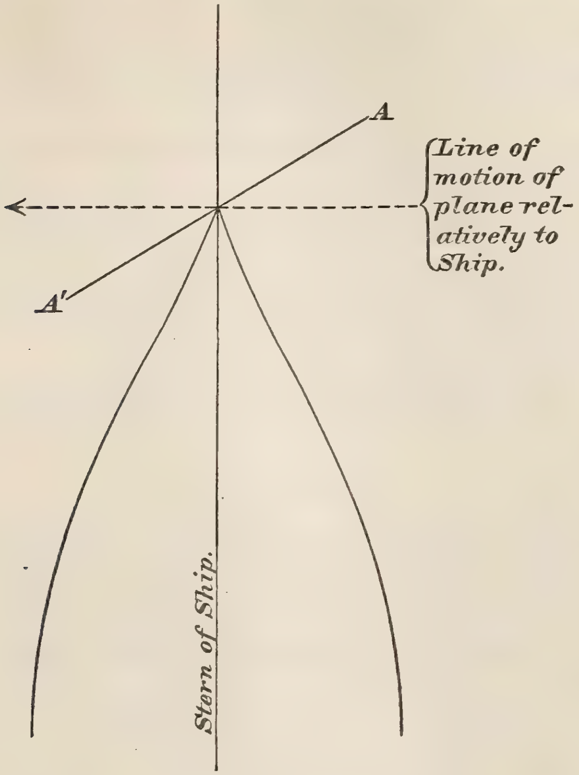
The Slip is the difference between the distance it would travel if working in a solid nut and the distance it does travel working in a yielding medium—water. The slip is usually expressed as slip ratio in percentage of the speed of the propeller; *i. e.*, if V=speed of propeller=pitch × revolutions, and v=speed of ship, then $V-v$=slip, and $\frac{V-v}{V} \times 100 =$ percentage of apparent slip.

The Area is all that portion of the propeller so shaped that its revolution about its axis causes a tendency to move along that axis.

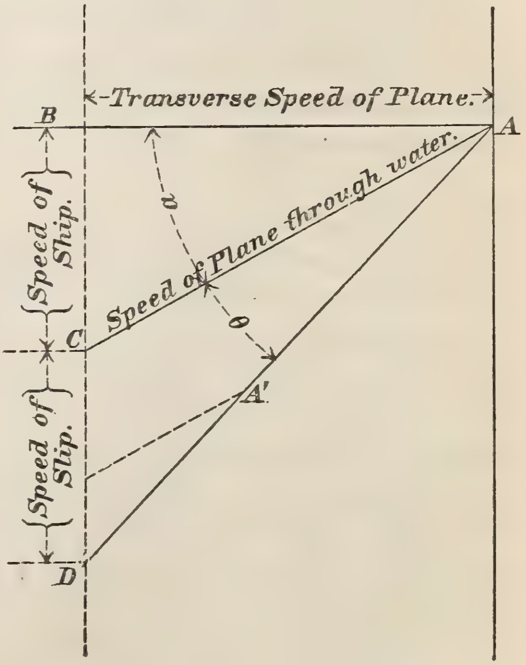
The two dimensions, pitch and area, are so intimately connected with slip that all three are considered under one head.

In April, 1878, a paper "On the Elementary Relation between Pitch, Slip, and Propulsive Efficiency" was read before the Institution of Naval Architects by W. Froude, esq., A. M., F. R. S., etc.

In that paper Mr. Froude likened the action of the propeller to that of an obliquely moving plane, or, to use his own words, "A true conception of the relation between the *modus operandi* of the obliquely moving plane and the blade of a screw-propeller may be found by imagining the plane to be carried round the screw axis by a perfectly strong radius of great length relatively to the size of the area and of indefinitely small thickness, the plane being set obliquely to the plane of rotation as if it were an unit of area in an extended true spiral surface. Thus viewed we see the action to be in principle the same as that of the action of the fish's tail, or of an oar used in sculling, although the action must be regarded as continuous instead of intermittent. And it is easy to see that the most essential of the dynamic elements of the action are simply those which would be in operation if a series of planes, the edgeway view of one of which is represented on plan by the line AA′ in the adjoining sketch, were being continuously moved transversely, with a definite steady speed past the ship's stern, actuated by machinery within the ship, each plane in its turn taking up the whole duty and its predecessor being supposed to be annihilated. Under these circumstances if the speed of the ship and the transverse speed of the planes is steady and continuous, a steady propulsive force is developed, and the speed will become steady also. In view of the elementary nature of the conditions to be elucidated, I shall disregard the ship's wake and imagine the action to take place in wholly undisturbed water.



"By the forward motion of the ship, the motion of the plane, which is purely transverse as regards the ship, becomes obliquely forward as regards the water; and the directions and magnitudes of the several elementary motions involved, and the attitude of the plane in relation to them, may be understood from the annexed diagram.



"As before, the line AA′ being the plane, as seen edgeways in plan, AB is the direction and speed of the plane's transverse motion relatively to the ship; call this speed V: BC is the direction and speed of the ship's forward motion; call this speed v: AC is the direction and speed of the compound motion of the plane through the water; call this speed v'.

"The difference between the direction of the plane itself, AD, and the direction of its motion through the water, AC, may be called the slip angle; and the speed of the slip taken account of in a direction parallel to the ship's motion is given by CD; call this speed S.

"Call the angle BAC the virtual pitch angle, say, α.

"Call the angle CAD the slip angle, say, θ.

"Call the angle BAD the actual pitch angle, say, $(\alpha + \theta)$.

"Then in the usual terms of screw propulson, the slip ratio is $= \frac{\mathrm{CD}}{\mathrm{BD}}$ or $\frac{\mathrm{S}}{v + \mathrm{S}}$

"If R be the propulsive force required to maintain the ship's speed, then, if we take dimensions in feet and time in seconds, the useful or effective work in foot-pounds done per second is Rv; and the problem to be solved is to apportion the area, and the angles α and θ, so as to make the effective work done bear the greatest ratio to the total work delivered to the propeller."

We will not follow Mr. Froude through the mathematical portion of his work, but simply mention the results, the foregoing having been introduced to enable the meaning of the terms used to be fully understood.

"The area which will drive the ship with a given slip ratio is directly as the ship's resistance, and is inversely as the square of her speed.

"In fact, to make the efficiency a maximum the slip angle must be directly as the square root of the coefficient of surface friction, and inversely as the square root of the coefficient of normal pressure; the value is, $\theta = \sqrt{\frac{f}{p}}$

"A still more curious and interesting conclusion is that which defines the pitch angle of maximum efficiency. If the slip angle be that which gives the maximum efficiency, then to produce the maximum efficiency the propelling plane ought to stand at an angle of 45 degrees with the line of the ship's motion; and this equally happens whatever be the coefficients of surface friction or of normal pressure.

"Taking as the coefficients of normal pressure and of surface friction those already mentioned (p=1.7 and f=0.008), the slip angle of maximum efficiency gives a slip ratio of 12½ per cent., and the maximum efficiency realized is about 77 per cent.

"The efficiency of a screw blade can not be so great as this, since only one region of the blade can have the most effective pitch angle.

"The most salient conclusions to which we are led by this review of the elementary principles on which the efficiency of the screw-propeller depends are (1), that a very much longer pitch than has been commonly adopted is favorable to efficiency; and (2) that instead of its being correct to regard a large amount of slip as a proof of waste of power, the opposite conclusion is the true one. To assert that a screw works with unusually little slip is to give a proof that it is working with a large waste of power."

For the area which will secure maximum efficiency Mr. Froude gives the equation $A' = \frac{R}{v^2} \times 8.9$, in which A'=blade area in square feet, R =resistance of ship in pounds at speed v, and v=speed of ship in feet per second.

The following foot-note at the end of Mr. Froude's paper is worthy of attention:

> Experiments which have been in progress since this paper has been in type show conclusively that the decrease of efficiency consequent on increased slip, with screws of ordinary proportion, is scarcely perceptible even when the slip ratio is as large as 30 per cent., with the screws working in undisturbed water. The results so shaped themselves as to point to the conclusion that for some reason or other the coefficient of surface friction began to diminish when the slip ratio became as much as 15 per cent., and was about halved when the slip ratio was 30 per cent.; and as it appeared not improbable that with increasing slip a more or less pronounced eddy might become established at the back of the blade, so as more or less completely to neutralize the friction on that surface, a rough experiment was tried by moving a plane obliquely through the water with various angles of slip, and in a position where the effect could be observed; and in point of fact it appeared that when the angle between the plane and its line of motion was about 10 degrees, the water at its back had assumed the form of an eddy, having nearly the speed of the plane, and that it in fact overran the plane when the angle was increased to 15 degrees.

From the foregoing we see that the area of blade is contained between two limits, the lower, that necessary to transmit the power, the higher, that where the power required to overcome the surface friction equals the propulsive effort.

The smaller limit, in smooth water and under normal conditions, is the more favorable to efficiency, but there are practical considerations which must not be overlooked, and the efficiency based on coal consumption is not the only efficiency to be considered. An ocean greyhound must make her time, and her *efficiency* is her ability to do so in all weathers. In steaming against a head wind and sea, or in overcoming any abnormal resistance, such as towing another vessel, a greater area than that necessary to transmit the power becomes necessary.

From a number of screws which give good results we find the average proportions to be, pitch, 1⅓ times the diameter, surface of blades, from .3 to .35 of the disk area.

Mr. Barnaby says: "The pitch should never exceed 2½ times the diameter."

NUMBER AND SHAPE OF BLADES.

From the result of a very valuable series of experiments with different screws made by Mr. Isherwood at Mare Island, Cal., in 1874, he draws the following conclusion: "* * * in the case of screws having the same kind and quantity of surface, their propelling efficiency, in smooth water, is not affected by either the number or position of their blades."

Numerous trials have been made to determine the best number from a practical standpoint, which is the only one necessary to consider.

Two blades give good results as regards propulsive efficiency, but cause excessive vibration, and their *disability ratio* is high. The loss of a blade means the loss of fifty per cent. of the propelling area, and an excessively unbalanced engine.

Three-bladed propellers have the same faults as two-bladed, but not to so great an extent.

Four-bladed propellers have given better results than any other form, increasing the number of blades beyond this apparently neither reducing the vibration nor increasing the efficiency.

In 1887 trials were made with two and four-bladed propellers on the *Ceram* and *Flores*, vessels of the Dutch Indian navy. There were three series of trials made; the first with a four-bladed screw, 9 feet diameter, 13 feet pitch, 30 square feet blade surface; the second with the same screw with two opposite blades removed; the third with a two-bladed propeller, 9 feet diameter, 11 feet 8 inches pitch, 17 square feet blade surface. All the screws of the Griffith pattern.

Mr. J. B. Andreœ discussed the results of the trials in a paper read before the Institution of Naval Architects, from which we extract the two following tables, showing the influence of the number of blades:

1	Revolutions	80	90	100	108	116	123	128
2	I. H. P. four-bladed propeller	200	300	400	500	600	700	800
3	I. H. P. two-bladed propeller	140	210	300	375	465	545	625
4	Difference between 2 and 3	60	90	100	125	135	155	175
5	Difference in percentage of 2	30	30	25	25	22	22	22

1	Speed in knots	8.7	9.7	10.6	11.35	12
2	I. H. P. four-bladed propeller	200	300	400	500	600
3	I. H. P. two-bladed propeller	180	275	375	480	625
4	Difference between 2 and 3	20	25	25	20	—25
5	Difference in percentage of 2	10	8	6	4	— 4

From the above it will be seen that the two-bladed propeller was more efficient than the four-bladed up to a speed of 11.8 knots, when the horse-power for the two was the same, 565. This loss of efficiency of the two-bladed propeller appears to have been caused by the vibration, which was excessive above that speed.

The shape of the blade has also been arrived at experimentally. In the early days of the propeller, but after it had passed the whole convolution period, it was customary to make the blades like a fan; that is, with the widest part of the blade near the tip. It was supposed that the greatest area at the point having the highest velocity would give the greatest efficiency. A better understanding of the action of the screw-propeller, especially as regards surface friction, has modified our views, until now the broadest part of the blade is at some distance from the tip.

As before quoted, Mr. Barnaby says, " The tip of the blade is very little good, only you must have a tip."

FRICTION.

Probably nothing affects the value of a screw as a propelling instrument so much as friction, and the amount of it is startling to one who has given the subject but little attention.

Mr. Froude says, " Take the case of a screw 20 feet in diameter making 80 revolutions per minute; the tips of the blades are traveling at a speed of about 50 knots. Now, the resistance of a surface so short in the line of motion as a screw-blade, even when its surface is quite smooth, is as much as $1\frac{1}{4}$ pounds per foot at 10 knots, and is nearly as the square of the speed, and as each square foot of blade area involves two square feet of skin, the resistance of each is over 60 pounds; thus, making some allowance for thickness and bluntness, there is involved in driving it at 50 knots at least 10 indicated horse-power, and collectively the outmost foot of four such blades, each 3 feet wide, would absorb fully 120 indicated horse-power in surface friction; and though the parts of the blade nearer to the root move with proportionately less speed, and therefore with less resistance, yet on the other hand screw-blades are generally ‘rough from the sand,’ and have probably a still higher coefficient of frictional resistance. The edgeways resistance offered by the blade is plainly analogous to that caused by its surface friction, and the same method of treatment will clearly apply to both circumstances; and obviously we are here dealing with an absorbent of power which can not be left out of sight as inconsiderable.

"As regards surface friction, the experiments I have conducted for the Admiralty show that it varies about as the power 1.85 or 1.9 of the speed. But for convenience we may adhere to the usual expression, that it varies as the square of the speed. The coefficient, or frictional force per square foot at unit speed, varies greatly with the length of the plane in the line of motion and the quality of the surface."

From the foregoing we get some idea of why the broadest part of the blade should not be at the tip, why a given area should not be sought for in excessive diameter, and why the area should be no more than that necessary to accomplish the given object. With a high piston speed, of which we are forced to take advantage owing to the consequent reduction in weight of machinery, goes a certain velocity of revolution, as practical considerations limit the length of stroke in marine engines, and with this speed of revolution, a large diameter of screw gives a peripheral velocity that soon absorbs in surface friction the propulsive effort of the outmost part of the propeller.

As another illustration of the influence of surface friction on the efficiency of propellers, take the case of the *Iris* as described by Mr. Barnaby:

"This ship was originally fitted with two four-bladed propellers 18 feet diameter and 18 feet pitch. She obtained a speed with these propellers of 15¾ knots with an expenditure of 6,369 I. H. P. Two blades were then taken from each propeller, reducing the total number from eight to four. The I. H. P. then required for the same speed was 4,369, or 2,000 less H. P., and this 2,000 I. H. P. was employed in driving the four additional blades."

It is hardly probable that all of this 2,000 I. H. P. was absorbed in surface friction, but there is no doubt that a large portion of it was.

POSITION OF SCREW.

Under this head, in his work on marine propellers Mr. Barnaby says: "It has been proposed, at various times, to place the screw in the bow, on either side of the bow, on either side amidships, on either quarter, and in a tunnel amidships. In a vessel recently built on the Thames one screw was placed in the fore-foot and one aft, in the usual position, working on the same shaft.

"It was intended to realize a speed of 18 to 20 knots. The highest speed obtained has been about 9 knots. How much of this failure is due to the position of the screws I can not say, but it is certain that the forward screw is in a very unfavorable position, as it causes a great increase in the surface friction of the hull.

"There is no doubt that the stern is the best position.

"As a vessel passes through the water the friction imparts motion to the layer of water rubbing against the sides and bottom. This layer increases in thickness towards the stern, so that, after the vessel has passed through, a considerable quantity of water is left with a motion in the same direction as the vessel.

"If the screw works in this water, it is able to recover some of the energy which has been expended by the ship in giving it motion. The speed of this wake, which Rankine estimates may be as much as one-tenth the speed of the vessel, does not depend upon the form, but upon the nature and extent of the surface. It would not be desirable to manufacture or increase the speed of the wake for the purpose of improving the efficiency of the propeller, because this very surface friction proves to be the largest portion of the resistance of the ship at moderate speed, but, as it is a necessity that there should be a wake, it is a distinct advantage to place the propeller in it, and allow it to utilize as much as possible of the energy it finds there.

"It is important not to confound this water, which has had motion given to it by the sides and bottom of the ship, with the wave of replacement; that is, the water filling in behind the ship. It should be the aim to avoid interfering with this motion as much as possible, as such interference augments the resistance of the ship very considerably, even in well-formed ships. It was thought at one time that the further aft the propeller could be placed, the better, but it is now believed that there is a position where the loss caused by the augmented resistance of the hull is more than balanced by the reduction of slip in the screw due to its working more in the water that has been rubbed by the vessel.

"In the small, high-speed steam launches, the propeller has been kept outside the rudder with advantage, but this is not practicable in the case of large steamers. All that can there be done is to make the run fine, so that the water has given out upon the stern of the ship the energy put into it by the bow before reaching the screw."

In the discussion which followed the reading of Mr. White's paper "On the Comparative Efficiency of Single and Twin-screw Propellers in Deep-draught Ships," Mr. John Scott Russell, F. R. S., said: "There is in every ship a most favorable place in which to put a screw; and the serious point is, where is that most favorable place? If you have two screws, you may put the screw propeller considerably forward on the body, and if you have one screw you may put that screw considerably aft on the body; and the question is, whether the two smaller screws placed forward on the body, or the single larger screw placed aft on the body, are the better propellers. Allow me to call your attention to this most important fact. You should study the speed at which that vessel is to be propelled, and its reference to her form. You all know that there is near the stern of the ship what we call a wave of replacement which has the following qualities—either that it comes in a good position in reference to the screw, or it comes in a bad one; and the question in regard to each ship is, whether you will place the screw immediately under the crest of this wave, or whether you place it in the bad position with the hollow of the wave near it or above it. Now, allow me to tell you the cause of this difference. On the crest of that wave the water is going forward in the direction of the ship, and contrary to the slip of screw. In this wave, in the same manner, at the top the water in the crest is going rapidly forward in the direction of the ship, and consequently is opposed to the screw; therefore, in these two positions the slip of the screw is greatly diminished. But in the hollow, on the contrary, the water is going in the opposite direction, and thereby the slip of the screw is greatly increased. In my opinion, where the ship is properly formed, it is so formed that at the given speed the crest of that wave will be in the plane of the screw, and then there will a minimum slip; and I think the efficiency of the twin screws will be found to be very materially dependent on having chosen for them the best place, and where those twin screws have proved a failure it will probably be found to be because they were put in the wrong place. What that place is you all know who have studied the wave system, because you know there is an exact point at which, with a given speed, the crest of the summit of the wave of replacement will be found. The one will be a good form for the twin screw, and the other will be a good form for a single screw. One point more in favor of the double screw is that in pitching, as the screw is a good deal lower under water, it will not be exposed so much to the inequalities as the other."

Mr. Robert Griffiths, in a paper entitled "On the Resistance given to Screw Ships by the action of the Screw Propeller, and how to remedy it," says, "As the ship moves forward the water closes in from each side of the stern to fill the space she occupied; when the screw is in operation it sucks away the eddy water at the top part of its disk, which mostly accumulates there, owing to the fullness of the run from the level of the screw-shaft to the top of the screw, which water would follow the ship if the screw did not draw it away, by which the thrust given to the screw-shaft is increased, and increases the resistance of the ship to nearly twice as much as it would have been had the screw not been in operation. The only remedy that I have been able to discover is to place the screw as far back from the tapered or wedge part of the stern as will allow the eddy-water to remain there, for which purpose the screw must be placed about two-thirds its diameter behind the stern-post, so that the currents which flow on each side of the dead-wood will be drawn by the action of the screw and meet in front of it, and supply it with water to act upon."

In his experiments Mr. Griffiths found that at a distance of two-thirds the diameter abaft the run, the screw gave a maximum speed, the speed decreasing at distances either greater or less than that.

Wherever the screw is placed it is very necessary to efficiency that the plane of the screw should be perpendicular to the direction of the ship's motion.

On this subject Mr Barnaby says, "There is a disadvantage connected with an inclined shaft which has been generally overlooked.

"The result of depressing the end of a screw-shaft is to cause the pitch of the propeller to vary through every part of the revolution. If the inclination is supposed to be 45 degrees, for example, that part of the blade which is intended to have a pitch of three diameters has a pitch in reality varying from nothing to infinity.

"It is, of course, obvious that the pitch of the blades of a screw *in relation to the axis* is unchanged by any alteration of the direction of the shaft.

"It is also clear that if a screw does not move along, but has a motion of rotation only, the opposition of the water is the same whatever be the direction of the shaft. But if the propeller be allowed to move along, while at the same time it be constrained to move horizontally, the shaft being inclined to the horizontal, then the opposition or resistance of the water is not uniform, but varies over every part of the revolution."

On the same subject Mr. Isherwood says: "The 'squatting' of the vessel not only increases its resistance in function of speed, but decreases the propelling efficiency of the screw by augmenting its slip beyond what is due to the resistance of the vessel. This augmentation of slip results from the inclination of the screw's axis to the direction of the vessel's motion, caused by the 'squatting' of the latter. If a given distance is passed over by the vessel in an hour, then, supposing its screw to have no slip and its axis to be horizontal, the speed of the screw (pitch × revolutions per hour) will be the same as that of the vessel; if, now, the axis of the screw be inclined to the horizontal, then, for the same speed of vessel as before, the screw will have to pass in the same time over a distance represented by the secant of the angle of inclination while the vessel passes over a distance represented by radius, and must now have a slip represented by the difference between the secant and the radius of the angle. Whatever slip the screw may have, under any conditions, an increased inclination of its axis will increase that slip in the manner described.

"The increased slip of the screw, due to increased inclination of its axis, may be further shown by forming a right-angled triangle, the base of which is represented by the speed of the vessel in any given time, the hypothenuse by the axis of the screw at the given angle of inclination, and the height by the vertical opposite the angle and cutting the hypothenuse. If the 'thrust of the screw' in the direction of its axis be represented by the hypothenuse, the portion of that thrust expended in propelling the vessel will be represented by the base of the triangle (supposed horizontal), while the portion represented by the height of the triangle will be wholly expended upon the water in the vertical direction, producing only displacement of that water, or slip to the full value of the vertical pressure. Of course, the vertical component of the thrust tends to lift the stern of the vessel, but if the weight of the stern is greater than the vertical component, and it almost always greatly exceeds it, this tendency will not produce any sensible result.

"Furthermore, every increase in the slip of a given screw is attended by an increase in the power required to be expended in overcoming the resistance of the surface of its blades to the water, because the greater the slip the oftener must the screw be revolved for a given speed of vessel, and the power expended in overcoming the resistance of the surface of the blades to the water is in the ratio of the cube of the number of revolutions made by the screw in a given time.

"Hence, the increased inclination of the axis of the screw of a given vessel, caused by the 'squatting' of the latter, increases all the losses of useful effect by the screw in a higher ratio than is due to the increased resistance of the vessel in function of speed. Both the power expended in the slip and in overcoming the surface resistance of the blades are increased by the 'squatting' beyond what is due to the same resistance of vessel without 'squatting.'

"A vessel, therefore, can only be forced above the speed at which 'squatting' commences by a disproportionate expenditure of engine power, the ratio of which disproportion rapidly increases as the 'squatting' becomes more and more. This is why, at high speeds of vessels, the engine power required increases so enormously above what is due to the theoretical law of the cubes of the speeds. The change in the form of the immersed solid of the hull, relatively to the water surface, and the exaggeration of useful effect by the screw, render impossible all calculation of the performance of a vessel beyond the speed at which squatting commences. Experimental knowledge in this case is the only guide.

"From the foregoing there evidently follows that the axis of the screw-shaft, for the maximum effect from a given screw, should be placed in such a position in the vessel that it will be horizontal when the vessel is at the intended speed. Any deviation from this position involves a loss of useful effect by the screw, unnecessary, and large in proportion as the angle of inclination of the axis to the horizontal is large."

Mr. Isherwood bases his remarks upon the change in trim of the vessel owing to defective replacement of the water at the stern, but all the arguments he has adduced, except that in reference to the change in form of the immersed solid of the hull, apply equally well to a shaft inclined from whatever cause.

IMMERSION.

On this subject Mr. Barnaby says: "With regard to the immersion, it appears that provided a screw is sufficiently far below the surface to prevent it from drawing air, any further immersion within the limits that can practically be obtained is of little value.

"The speed with which water can follow up the blades of a screw depends upon the head of water over it, but when the immersion is sufficient to exclude air, a head of water equivalent to 30 feet is supplied by the atmosphere; this is a fact which has been overlooked by many writers, but was clearly pointed out by Prof. Osborne Reynolds.

"We found by experiments on the model of the Thornycroft screw that the efficiency, which is as much as 70 per cent. when properly immersed, falls to about 50 per cent. when breaking the surface of the water.

"As a result of a change from a diameter of 5 feet 10 inches to 4 feet 6 inches, the speed of the first-class torpedo-boat was increased from 18 to 20 knots, other conditions remaining the same. This a most important feature in the screw.

"It is a common thing to see screw-steamers, in their light condition, with the tips of the blades of the propeller 2 feet to 3 feet above the surface. This implies an immense loss of efficiency."

RACING.

Racing is the term applied to the non-uniform speed of revolution of the screw from any cause whatever, though usually restricted to external causes. Of these latter Mr. Barnaby says: "The racing of screws is due to either of two causes:

"If the propeller breaks the surface of the water as the stern rises in a seaway, it will draw air down, and the resistance is immediately very much reduced. Referring to Fig. 9, showing the thrust at a given number of revolutions of a propeller, in one case completely immersed and also when splashing, we see that in the former condition it exerts a thrust of 11 pounds at 680 revolutions.

"When it is drawing air the same thrust is exerted at 1,000 revolutions, so that we see that this propeller, if delivering a constant thrust, would vary its revolutions instantly from 680 to 1,000 if alternately raised and lowered as in the action of pitching. But it is not always when the screw breaks the surface of the water that it will race. When a vessel is pitching heavily there may be racing, even although the screw does not rise within several feet of the surface."

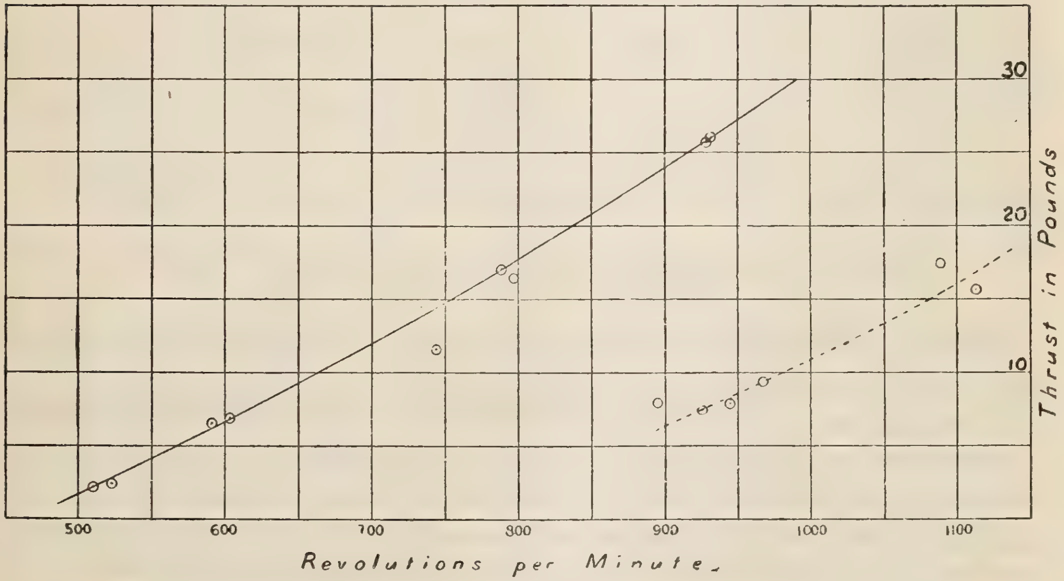


FIG. 9.

"Mr. Froude pointed out that this was probably due to the oscillating motion of water in waves. There is no real motion of translation in waves. The water which is traveling in one direction at the crest returns in the opposite direction in the trough of a wave. This oscillating motion of the water extends to some distance below the surface. A screw, therefore, finds the resistance of the water alternately augmented and reduced, as it is beneath the trough or crest of a wave, and reduces or increases its speed accordingly."

VIBRATION.

Mr. Griffiths, in describing a screw of his invention, so constructed that the blades always meet with the same resistance, gives the following explanation of vibration:

"When a screw is working, the blades, as they pass over the top part of the disk, meet with more resistance than when they are passing over the bottom part, for, as the screw, to obtain the thrust, drives back a column of water the size of the screw's disk at a velocity corresponding to the power employed, it has to accelerate the velocity more at the top of the disk than at the bottom, and consequently more power is expended on the top part of the disk than on the bottom, and from this cause the increase of the resistance of the ship from the action of the screw, which Mr. Froude has proved is always from 40 to 50 per cent. of the total resistance of the ship, is considerably more than if the power were uniformly expended over the disk, for the ship is much retarded by the drawing of the dead-water (so to speak) from the top of the disk, whereas accelerating the currents at the bottom of the disk would have hardly any effect on the ship. Again, as the blades one after another pass over the top part of the disk, and as each blade meets with an increase of resistance there, a series of jerks is given to the vessel, which is the cause of vibration."

Speaking of the trials of the *Destructor*, Mr. Biles said: "* * * when the screws of the *Destructor* made 310 revolutions, the intended speed, the vibration was synchronous with the boat, and became too violent; so they tried a great number of screws, and at last settled down to 292 revolutions, at which speed the engine action was not rhythmical with the boat, and the vibration was arrested and not excessive."

MATERIAL AND CONSTRUCTION.

Cast-iron is the material most commonly employed in the construction of the screw propeller, as it is the cheapest of the metals available for this purpose. The greatest objection to it is its liability to fracture.

Mild-steel is much stronger, but is very subject to corrosion. The shape of a finished steel blade is not always that intended, owing to its liability to twist both in casting and annealing. Both tin and brass have been applied to steel blades to prevent corrosion, but with indifferent success.

Gun-metal propellers have been attended with good results, but owing to their great cost they have been confined principally to Government vessels. The stern frames and plates of iron and steel vessels having gun-metal propellers have to be protected by zinc from the pitting caused by galvanic action. In casting gun metal propellers care must be taken to prevent segregation, especially in the heavier parts.

Manganese-bronze has been used extensively for propeller blades. The manganese is introduced as ferro-manganese or metallic manganese, but it is said that no trace of manganese is found in the castings, its function being to promote the mixing of the other constituents. Manganese-bronze does not pit, but zinc protection is required for the hull as with gun-metal.

Phosphor-bronze also gives good results. Delta-metal and aluminium-bronze have also been used.

The foregoing is taken from a paper on the "Material best suited for Propeller Blades," by Mr. W. C. Wallace, of Dumbarton. Other information from the same source is contained in the following table:

Material of propeller.	Ultimate tensile strength in tons per square inch.	Elongation.	Weight required to break a rectangular bar 1″ by 1″ and 12″ between supports.
		Per cent.	*Cwt.*
Cast-iron	8 to 12	Nil	16 to 20
Mild-steel	28 to 34	6 to 12	50 to 60
Gun-metal	12 to 16	1½ to 5	20 to 26
Manganese-bronze	12 to 17	....	28 to 45
Phosphor-bronze	15.8	17½	24
Delta-metal	15 to 23	10 to 20	....

In the discussion which followed the reading of Mr. Wallace's paper, Mr. G. W. Manuel, superintendent engineer to the Peninsular and Oriental Steam Navigation Company, said that in 1880 they had much trouble from ships breaking off the cast-iron blades of propellers in going through the Suez Canal and from the loss through failures in manufacture, and also from corrosion, by means of which the blades became blunted. In order to get out of these difficulties they had recourse to steel, using a very ductile metal supplied by Vickers.

Blades made from this would bend when struck, and this settled the breakage problem. But they found the corrosion was greater with steel than iron. In order to meet this difficulty soft brass plates were put on the surface of the part corroded, being attached by screws. Latterly the plates were let in flush, great care being taken in fitting them. This plan was so far successful that the plates would sometimes last six years, sometimes only three years. The average efficiency was four years. They next made a sheathing of brass to lap over the blade, and thus form a cutting edge. Propellers fitted in this way were still running. On the whole, though, it was concluded that steel was not the right material, and about this time manganese-bronze came into the market. They hesitated in adopting this alloy, because they had heard of a good many breakages of blades made from manganese-bronze. On inquiry, he found that the failure had been in blades not made by the Manganese Bronze and Brass Company, Mr. Parsons, the manager, informing him that none of their metal had given way. It was, therefore, determined to give the metal a trial. The following are some of the results obtained with one of the company's vessels, the *Ballarat*, on an Australian voyage from England and home again:

	Speed.	Coal per day.	Indicated horse-power.	Slip of screw.
Steel blades	12.11	63.8	2,828	13.1
Bronze	12.35	55.0	2,577	9.7

The diameter, pitch, and surface of the propeller were the same in both cases. These figures are a mean for the whole voyage, and show an increase in speed of .24 knot per hour, and a saving of 8.8 tons of coal per day in favor of the bronze blades, or a total saving on the voyage of 715 tons. The displacements and the weather were alike on each occasion. The company then determined to fit manganese-bronze blades to one of the two ships then building, the *Victoria* and the *Britannia*.

The following is a comparison of the trial-trip results:

Ship.	Material of propeller.	Steam.	Revolutions.	Indicated horse-power.	Speed.	Displacement.	Slip.
							Per cent.
Victoria	Manganese-bronze	146	63	6,080	16.52	8,124	8
Britannia	Steel	146	64	6,203	16.47	8,040	10

The propellers of both vessels were alike as regards diameter, pitch, and surface. The results of the various trials were to impress the speaker with the fact that manganese-bronze propellers were more effective than those of steel. He thought one great advantage with manganese-bronze was the thinner edge that could be got. He did not place so much value upon thinness in the central part, as when their cast-iron blades broke they thickened them 2 inches, and got the same speed with the same power.

The subject of manganese-bronze for screw-propellers has again been brought to the front by the late hurricane at Samoa. The London Engineer of May 10, 1889, says editorially:

"The escape of Her Majesty's ship *Calliope* from the harbor of Apia, at Samoa, when the German and American squadrons had to succumb to the fury of the hurricane, was recently noticed in our columns, reference being made to the excellence of the engines with which the vessel is fitted, by means of which she was enabled to make headway against the storm. On this topic something more may yet be said, and the subject is one well deserving full consideration. Coupled with the engines, there is the propeller; and although at first the allusion may excite an incredulous smile, yet the fact that the screw of the *Calliope* was made of manganese-bronze will be found, after a little investigation, to be a circumstance that ought not to be disregarded. We refer to the subject not merely for the sake of demonstrating the advantage which there is reason to believe the *Calliope* derived from the character of her propeller, but in order to deal with certain data, by which it would appear that a screw of this description really offers a substantial gain in the matter of speed. It is to be remembered that the *Calliope* made her way against the storm simply at the rate of half a knot per hour; of course her inherent speed was considerable, but the storm neutralized the whole of it, except this small balance left in the ship's favor. What may be termed the effective speed was very little, but that little was sufficient to save the ship. The *Calliope* may never encounter the like dilemma again, and it may rarely happen that an extra half knot per hour will rescue a ship from destruction. Yet this little half-knot, continuously maintained, is not to be despised, especially on a long voyage. Or, if the extra speed is not desired, a saving of fuel may be effected, representing in the aggregate a very appreciable sum of money. Reasons are forthcoming why a screw propeller made of manganese-bronze should give a better rate of speed than one of gun-metal or steel, or any other metal yet known. But in the first place, we may fall back on ascertained facts. It may be readily conceded that a commercial body like the Peninsular and Oriental Steam Navigation Company would not enter upon an extensive adoption of manganese-bronze for the screws of its steam-ships, unless there was some practical advantage to be gained by doing so. Eleven of its ships are thus equipped, and a striking example on this point was mentioned a year ago before the Institution of Naval Architects, by Mr G. W. Manuel, the company's superintendent engineer. The screw-blades of the *Ballarat*, made of steel, had been exchanged for others made of manganese-bronze. In this instance, although the gain in speed was only about a quarter of a knot per hour, the effect was seen in a saving of between 8 and 9 tons of coal per day, or a total of 715 tons on the voyage out and home between England and Australia. The saving in coal represented about half the first cost of the bronze blades. This comparison is the more valuable, owing to the fact that the diameter, pitch, and surface of the propellers were the same in both cases.

"Another very striking instance is furnished by the *Australia* and *Zealandia*, two steam-ships in the mail service between Australia and San Francisco. These ships, originally fitted with steel propellers, had manganese-bronze blades of exactly the same surface and pitch substituted. The speed was then found to be increased nearly one knot per hour, and the passage was made in two days' less time. A very satisfactory pecuniary result has been secured with regard to these vessels by the acquisition of postal premiums, the amount being such as to pay many times over for the cost of fitting the new propellers. Eight ships of the White Star line have propellers of manganese-bronze, as well as two belonging to the Cunard Company. On the Inman Line we have the *City of New York* and the *City of Paris*, the latter famous for her extraordinary speed just accomplished on her first voyage to America and back. The Pacific and Orient Steam Navigation Company has manganese bronze propellers for the *Orizaba*, the *Oroya*, and two other vessels of its line. The North German Lloyd Steamship Company has done the same with eight of its ships. One of these, the *Lahn*, of 8,000 indicated horse-power, lately made a remarkably rapid passage. Some time ago the Scottish Oriental Steamship Company substituted manganese-bronze propellers for others of iron and steel in four of its ships, the increased speed ranging from two-thirds of a knot to one knot per hour. The four other steamers belonging to this company were fitted with bronze blades when built. Other instances might be mentioned, but these will indicate the appreciation which steamship companies have entertained for this particular kind of bronze, and there is every prospect that the use of the metal for propellers will extend. Outside the circle of the mercantile marine we have the example of the British Admiralty. The *Colossus* was fitted with twin screws of manganese-bronze after a series of experiments on the strength of this material as compared with gun-metal, the trials being made at the works of Messrs. Maudslay, Sons & Field, in the presence of the admiralty inspector, with the result that the manganese-bronze was found to possess just double the strength of gun-metal. Consequently the adoption of the bronze effected a saving of from 20 to 25 per cent. in the weight of the propeller. In addition to the *Colossus* and the *Calliope*, manganese-bronze has been employed for the propellers of the *Calypso*, *Rover*, *Rattlesnake*, and *Sandfly*. The French Government have adopted the same metal for the twin screws of the *Tage*, *Cécille*, *Forbin*, *Surcouf* *Troude*, *Lalande*, and *Cosmao*. The Russian Government have taken the same course with regard to the *Admiral Korniloff* and the *Rinda*.

"We may now say something as to the probable cause of the advantage given by manganese-bronze when this metal is employed in the construction of screw propellers. A particular kind of manganese-bronze is used for this purpose. There are five different qualities of the metal, that of which the propellers are made possessing great strength and toughness. We have already mentioned the proof of this in the trials made in the presence of the admiralty inspector. The transverse strength of the metal is stated to be about equal to that of the best cast steel. Hence, as compared with gun-metal, a great reduction can be effected in the thickness of the blades, which therefore become finer and sharper. There is also a peculiar smoothness of surface, producing a diminution of skin friction, especially important where high rates of speed are employed. A velocity of 40 or 50 miles per hour in the extremities of the blades gives value to everything which reduces the unproductive resistance. The power thus saved is utilized in giving greater speed to the vessel. Steel castings for propeller blades are very rough, and are almost always out of true pitch, owing to the warping which they undergo in the annealing furnace;

whereas the manganese-bronze blades are almost mathematically true, as shown when tested by the pitchometer. This metal has the advantage over steel of being more fluid when melted, thereby producing a finer casting. Freedom from pitting and corrosion preserves the blades for a long time in their original form, so that the life of a bronze blade may be reckoned as equal to that of the ship to which it is attached. So great is the saving of weight in the construction of a manganese-bronze propeller, that the reduction in the outlay for raw material renders the price about equal to that of a propeller made of gun-metal, although weight for weight the bronze is from 20 to 25 per cent. dearer. There is also the recommendation that the manganese-bronze propeller will fetch a good price as old metal. As compared with steel, manganese-bronze is about three times dearer at the outset. But the pitting which so soon takes effect on steel greatly enhances the cost in the course of years, so that after the lapse of a certain period that which appeared the dearest proves to be the cheapest. Taken all in all, there is accordingly much to be said in favor of manganese-bronze. In these days when 'commerce destroyers' are in vogue with foreign navies, and vessels to catch these 'destroyers' are specially needed in the navy of England, it is well that we should not only know how to make powerful engines, but how to apply such power to the most efficient and enduring propeller. For this purpose we shall expect to find manganese-bronze growing in favor as time goes on."

The following is an abstract of the engineer's log of the S. S. *Zealandia*, referred to in the above:

No. of voyage.	Time under way.	Average pressure of steam.	Average revolutions per minute.	Average speed per hour.	Average slip.	Average quantity of coal per voyage.	Remarks.
	Outward, from Sydney towards San Francisco.						
	D. h. m.	*Pounds.*		*Knots.*	*Per cent.*	*Tons.*	
5 to 17	26 14 11	64	55.3	11.47	16.0	1,099	Cast-steel blades.
18	24 3 30	66	59.3	12.48	14.8	1,100	Manganese-bronze.
Increase				1.01			
	Homeward, from San Francisco towards Sydney.						
5 to 17	25 15 32	64	56.5	11.76	15.6	1,093	Cast-steel blades.
18	23 17 10	70	61.0	12.74	15.3	1,122	Manganese-bronze.
Increase				0.98			

Propellers were formerly cast in one piece, either from a pattern or by sweeping up. This method, except in the case of small screws, has gradually been abandoned. The hub or boss and the blades are now cast separately, and the blades bolted to the boss. The flange of the blade is countersunk into the boss, and is circular in section in a plane perpendicular to the radius of the blade. The bolt holes in the flange are usually elongated in the direction of the circumference of the flange, permitting the blade to be rotated through a small angle, thereby altering the pitch. The nuts should be countersunk into the flange and locked. The boss should then be covered with a metallic sheathing, or the countersinks filled with some suitable composition, so as to give to the boss a fair spherical surface. A conical tail-piece should be secured to the after side of the boss, covering the nut on the end of the shaft, and preventing the formation of eddies.

The boss should be accurately fitted to the shaft, and secured both by keys and a nut on the end of the shaft. The keys should be of ample section and carefully fitted. The nut on the shaft should have a thread contrary to that of the propeller.

The following on the manufacture of screws for torpedo-boats is taken from Barnaby's Marine Propellers:

"In torpedo-boats the general practice is to make the blades of hammered steel and to key them on to the boss, as shown in Fig. 10.

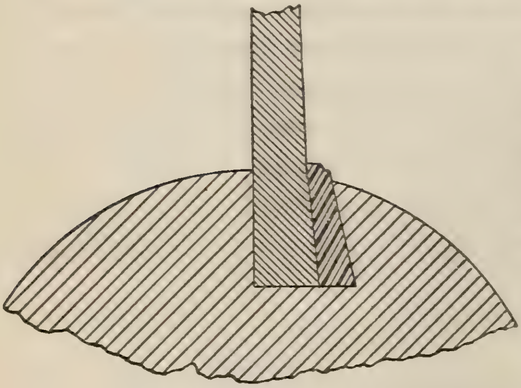


Fig. 10.

"The root of the blade is made wedge-shaped as well as the key, the latter being tapered in the direction of its length also. When this key is driven hard in, the blade is held absolutely fast without any projecting bolts or flanges. By making the blades of forged steel, they can be made very thin and sharp, which is a matter of great importance.

"A forged propeller is made as follows: A wooden block is first prepared from the drawing. This is built up of layers of wood of equal thickness, the section of the blade at each layer being given on the drawing. From this block an iron one is cast.

"The blades are first forged flat and made roughly to the proper thickness and shape. They are then hammered on to the cast block and given the required twist.

"The roots are planed, and the blade ground smooth on a grindstone, care being taken that each blade shall weigh the same when finished. They are then keyed into the boss, also of forged steel, the grooves of which have been slotted to the required angle. The propeller is finally put upon a mandril and balanced. In order to do this it is of course necessary that not only shall the blades be of the same weight, but that the centre of gravity of each blade shall be at the same distance from the centre of the boss. When thus carefully balanced, the screw causes no vibration in the boat."

CORROSION.

The corrosion of iron and steel propellers seems to be confined to certain parts of the blades. On the driving face it is along the leading edge, decreasing from the tip towards the root. On the back it covers the blade running out at the leading edge at about the same point as on the driving face, and at the trailing edge at some point much nearer the tip. This corrosion not only weakens the blade, but so roughens the surface as to greatly increase the friction. Besides the efforts made to prevent this mentioned under the head of Material and Construction, covering the blades with vulcanite, Portland cement, and other compositions has been tried, but with poor success.

In changing the material of the propeller to bronze we preserve the screw at the expense of the ship, the corrosion, or pitting, now taking place upon the iron or steel of the stern, which in turn has to be protected. The action in this case, galvanic, is produced by the immersion of two dissimilar metals in the oxidizing fluid, salt water, which completes the battery. The stern frames and plates of the ship are protected by zinc.

Mr. Willis of the "Specialty" steel works, Attercliffe, has invented a method of copper coating propeller blades. A copper plate properly bent in shape is placed in and forms part of the mould, into which the iron or steel is then poured, with the result that the copper is said to be firmly united by fusion to the iron or steel face.

MULTIPLE SCREWS.

As the name implies, multiple screws embrace all cases in which there are more than one. The most common and the one to be first considered is the case of two screws, or, as they are more often called,

TWIN SCREWS.

Twin screws were first used in 1853 to assist in manœuvring. Not until 1870, however, were trials made and results recorded from which a fair comparison with single screws could be made. In that year trials were made of the twin-screw ships *Vanguard*, *Invincible*, and *Iron Duke* at Plymouth, and of the *Captain* in Stokes' Bay.

The results of these trials have been tabulated and compared with the performances of the single-screw ships *Swiftsure* and *Triumph* at Plymouth, and the *Bellerophon*, *Monarch*, *Hercules*, *Sultan*, and *Independencia*, in Stokes' Bay, and formed the subject-matter of a paper read before the Institution of Naval Architects in 1878, by Mr. W. H. White, the present assistant controller and director of naval construction of the British navy.

The particulars are recorded in the following Tables I and II;

TABLE I.

	Single screws.		Twin screws.			
Name of ship	*Swiftsure.*	*Triumph.*	*Vanguard.*	*Vanguard.*	*Invincible.*	*Iron Duke.*
Length between perpendiculars	280 ft.	280 ft.	280 ft.	280 ft.	280 ft.	280 ft.
Breadth extreme	55 ft.	55 ft.	54 ft.	54 ft.	54 ft.	54 ft.
Mean draught on trial	24 ft. 9½ in.	25 ft. 7½ in.	22 ft. 6 in.	21. 0 ft.	21. 0 ft.	21. 0 ft.
Displacement in tons	6, 537	6, 840	6, 076	5, 563	5, 563	5, 563
Area of immersed midship section, square feet	1, 140	1, 186	1, 077	996	996	996
Area of wetted surface, square feet	22, 120	22, 620	21, 750	20, 850	20, 850	20, 850
Character of bottom	Coppered.	Coppered.	....	Iron, clean	painted.	....
Screw propellers:						
Description	Griffiths.	Griffiths.	Mangin.	Mangin.	Mangin.	Griffiths.
Number of blades on each	2	2	4	4	4	2
Area of surfaces of blades, square feet	137	137	304	304	304	209
Diameter	20 ft.	20 ft.	16 ft. 2 in.	16 ft. 2 in.	16 ft. 2 in.	16 ft. 6 in.
Pitch	24 ft. 6 in.	24 ft. 6 in.	20 ft. 9 in.	20 ft. 9 in.	20 ft. 9⅞ in.	19. 0 ft.
Immersion of upper edge	4 ft. 1 in.	5 ft. 1 in.	4 ft. 4 in.	2 ft. 10 in.	3 ft. 5 in.	3 ft. 3 in.
Area of propeller disk, square feet	314	314	412	412	412	428
Revolutions per minute on trial	68. 4	67. 85	72	73. 7	70. 8	81. 2
Trials:						
Where tried	Plymouth.	Plymouth.	Plymouth.	Plymouth.	Plymouth.	Plymouth.
When tried	Jan. 11, 1872.	Mar. 19, 1873.	Oct. 15, 1870.	April 7, 1870.	Sep. 26, 1870.	Aug. 18, 1870.
Force of wind	2 to 3	5	2	2 to 3	1	1
State of sea	Moderate.	Smooth.	Smooth.	Smooth.	Smooth.	Smooth.
Indicated horse-power	4, 913	5, 114	5, 312	5, 366	4, 832	4, 789
Speed of ship, in knots	13. 755	13. 522	14. 076	14, 944	14. 093	13. 855
Slip of screws—per cent	16. 79	17. 57	4. 6	. 93	1. 89 (neg.)	8. 99
At 14 knots:						
Indicated horse-power	5, 275	5, 875	5, 200	4, 140	4, 710	4, 995
Indicated horse-power per square foot of wetted surface	. 2385	. 2597	. 2391	. 2	. 2259	. 2396

TABLE II.

	Single screws.					Twin screws.		
Name of ship	*Bellerophon.*	*Monarch.*	*Hercules.*	*Sultan.*	*Independencia.*	*Captain.*	*Alexandra.*	*Temeraire.*
Length between perpendiculars	300 ft.	300 ft.	325 ft.	325 ft.	300 ft.	320 ft.	325 ft.	285 ft.
Breadth extreme	56. 0 ft.	57 ft. 6 in.	59 ft.	59 ft.	63 ft.	53 ft. 3 in.	63 ft. 8 in.	62 ft.
Mean draught on trial	23 ft. 11½ in.	23 ft. 8½ in.	24 ft. 8¼ in.	24 ft. 10¾ in.	24 ft. 8 in.	24 ft. 10 in.	26 ft. 1½ in.	27 ft.
Displacement, in tons	7, 236	8, 070	8, 676	8, 714	8, 950	7, 672	9, 432	8, 571
Area of immersed midship section, square ft.	1, 188	1, 208	1, 313	1, 320	1, 453	1, 176	1, 405	1, 455
Area of wetted surface, square feet	25, 400	27, 450	28, 000	28, 140	25, 430	26, 260	29, 620	26, 900
Area of curved surface of bottom (exclusive of bilge keel, etc.), ÷ (displacement) $\frac{2}{3}$.	59. 6 ft.	61. 4 ft.	60 ft.	60 ft.	58. 3 ft.	62 ft.	59. 7 ft.	57. 2 ft.
Character of bottom	....	Iron, clean	painted.	....	Coppered.	Iron, clean	painted.	Zinc, clean painted.
Screw propellers:								
Description	Griffiths.	Griffiths.	Griffiths.	Griffiths.	Griffiths.	Griffiths.	Mangin.	Griffiths.
Number of blades on each	2	2	2	2	2	2	4	2
Area of surface of blades, square feet	210	254	210	210	136	200	473	263
Diameter	23 ft. 6 in.	23 ft. 4 in.	23 ft. 6 in.	23 ft. 7 in.	22 ft. 6 in.	17 ft.	21 ft.	20 ft. ½ in.
Pitch	20 ft. 1 in.	26 ft. 4 in.	24. 0 ft.	24 ft. 1 in.	23. 0 ft.	21 ft. 8 in.	22 ft. 2¾ in.	22 ft. 6 in.
Immersion of upper edge	2 ft. 2 in.	1 ft. 4 in.	1 ft. 11½ in.	2 ft. 4 in.	1 ft. 11 in.	4 ft. 10 in.	3 ft. 3 in.	4 ft. 11 in.
Area of propeller disk, square feet	434	428	434	434	398	454	692	628
Revolutions per minute, on trial	75	63. 6	71. 5	71. 5	70. 5	74. 3	64. 2	73. 8 ft.
Trials:								
Where tried	Stokes' Bay.	Stokes' Bay.	Stokes' Bay.	Stokes' Bay.	Maplin.	Stokes' Bay.	Stokes' Bay.	Stokes' Bay.
When tried	Aug. 17, 1866.	July 17, 1869.	Jan. 1, 1869.	April 19, 1871.	Feb. 2, 1878.	Mar. 2, 1870.	Feb. 28, 1877.	Sept. 17, 1877.
Force of wind	5 to 6	1 to 2	2 to 4	4 to 5	....	3 to 4	4	4
State of sea	Little swell.	Calm.	Smooth.	Smooth.	....	Smooth.	Smooth.	Smooth.
Indicated horse-power	6, 521	7, 842	8, 529	8, 629	8, 832	5, 990	8, 615	7, 516
Speed of ship, in knots	14. 17	14. 94	14. 69	14. 13	14. 6	14. 24	15	14. 65
Slip of screws—per cent	4. 73	9. 65	13. 26	16. 85	8. 75	10. 47	6. 5 (neg.)	10. 5
At 14.6 knots:								
Indicated horse-power	7, 350	7, 151	8, 320	9, 835	8, 832	6, 619	7, 732	7, 413
I. H. P. per sq. ft. of wetted surface	. 2894	. 2651	. 2972	. 3495	. 3473	. 2521	. 261	. 2756

In the discussion which followed the reading of Mr. White's pa many references were made to the *Iris*, which at that time had m her first trial and failed as regards speed. To that failure we proba owe much of our present knowledge of the screw propeller. Owing the deficiency in speed, over a knot below that expected, a series progressive trials was made, the results of which are fully recorded an explained in a paper read before the Institution of Naval Architects 1879, by Mr. James Wright, at that time engineer-in-chief of the Adı ralty.

One of the chief objections urged against twin screws was the i creased resistance caused by the shafts and their supports on the outside of the ship.

In regard to this Mr. Linnington says: "With twin screws in a suitable position the fineness of the run of high-speed ships necessitates a great length of shafting outside the ship, and the distance between the stern tube and stern bracket is sometimes too great for the shaft to run unsupported if made of the ordinary diameter. Intermediate bearings have been used, but the most recent practice is to use a hollow steel shaft of enlarged diameter between the bearings, as shown in the sketch (Fig. 11), which illustrates the arrangement in the *Mersey* class of cruisers, where the length between the stern bracket and stern tube is nearly 45 feet.

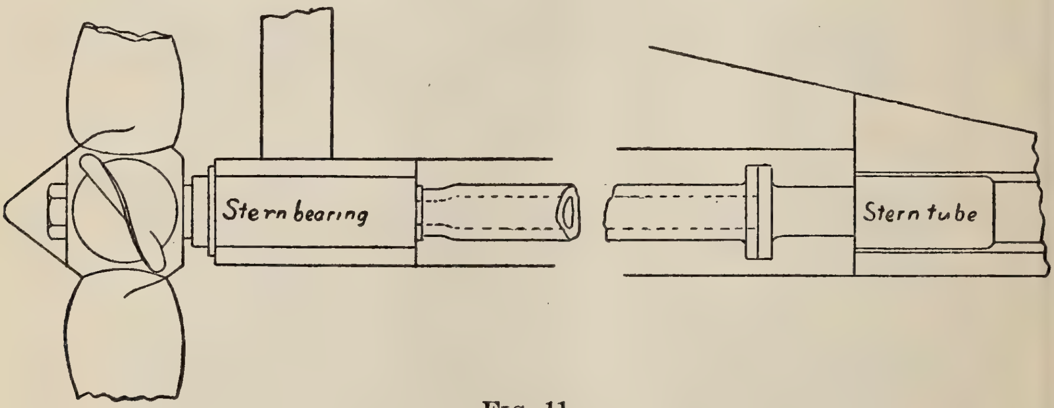


FIG. 11.

"This, simple as it appears, must be regarded as a great improvement, as the intermediate inaccessible bearing is dispensed with, and its bracket or other support is not required. The removal of the bracket effects a considerable reduction of the resistance due to the hull appendages of the twin screws."

In the steam-ship *City of New York* the tubes which carry the propeller shafts are supported by brackets in the usual way, each one of which is a massive steel casting weighing 26 tons, and also by stiffening webs.

In the early days of twin screws it was thought that the propellers, on account of their position, would be liable to accident, and Sir Edward Reed stated that in sending three gun-boats to India by way of the Suez

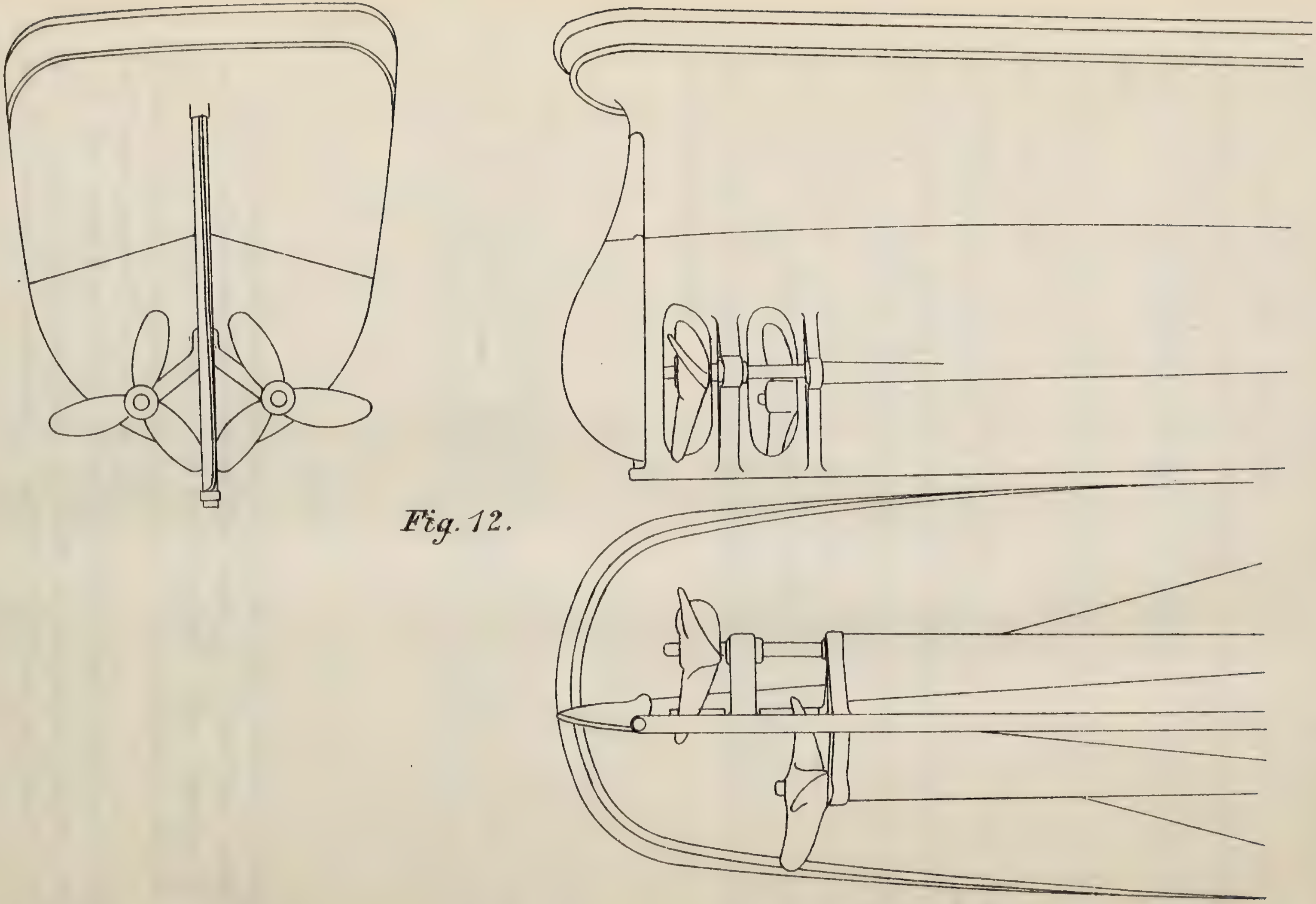


Fig. 12.

Canal the vessels with single screws passed through the canal all right, while the one with twin screws damaged her propellers considerably. On the other side, however, Mr. Hill, managing owner of the Hill Line, stated that no difficulty was experienced in taking their ships into dock; in fact, the twin-screw ships of 420 feet in length were taken into dock at less expense than those with only one screw, owing to their greater facility in manœuvring, permitting them to do away with the assistance of tugs.

Mr. Alexander MacLaine, of Belfast, introduced an ingenious arrangement of twin screws to lessen the liability to damage. He overlapped the screws by bringing the shafts closer, putting one screw forward of the other, and cutting away the dead-wood to permit the tips of the blades to pass. This device in all probability decreases the efficiency slightly, but accomplishes the object desired.

The screws of the White Star steamers *Teutonic* and *Majestic*, now building, are arranged in this manner. (See Fig. 12.)

One advantage of twin screws which appears to be overlooked by most writers is the uniformity of speed in all weathers. Upon this subject Mr. A. E. Seaton says: "We have built during the last two or three years seven twin-screw boats; some for the South Eastern Railway, some for the Great Eastern Railway, and some for the Manchester, Sheffield and Lincolnshire Railway. All those boats have one peculiarity, and it is worthy of notice, * * * that is, the uniformity of speed maintained by them in any weather. The Great Eastern Railway boats run from Antwerp to Harwich, and are timed to arrive at Harwich with their paddle-boats which sail from Rotterdam. Their newer paddle-boats are quite as fast in smooth water as the twin-screw boats, and it is not an uncommon thing on a fine night for the paddle-boat to be either neck-and-neck or a little before the twin screw, but directly there is a little bit of hubbub at sea, or a head wind, or even a beam wind, the paddle-boat is always late, while the screw is only a very little behind her time. In fact, in the gales of the winter before last those boats, in the stormiest weather, were rarely more than an hour late at Harwich, whereas the paddle steamers were four to eight hours late. The same remarks apply to the boats running from Folkestone to Boulogne."

In speaking of the action of these twin-screw boats in very bad weather Mr. Seaton says: "It seemed as if when one engine wanted to race the other took the steam from it. At all events there appeared to be very great uniformity of motion in the screw. * * * "

TRIPLE SCREWS.

In 1884 and 1885 the French Government conducted a series of trials with a steam launch called the *Carpe*, built for the purpose, and fitted with three screws.

In 1886 M. Marchal read a paper before the Institution of Naval

Architects, based upon the results of the *Carpe's* performances, from which we abstract the following:

"The object of increasing the number of propellers is to obtain certain fighting qualities, but not to realize an increased efficiency."

The principal object of the trials was to decide which of two arrangements of the lateral screws gave the better result, especially as regards mutual interference; one position, in the same transverse plane as the central screw, and the other situated more in advance, the shafts being also brought closer together so as to avoid all projection of the propellers beyond the lines of the hull.

The experiments were divided into series according to the positions of the lateral screws.

The *first series* comprised all those trials in which the extreme screws were in the same transverse plane as the central screw.

In this series the following propellers were tried successively:

Three screws of 44^{cm} diameter, the ratio of pitch to diameter being 1.25.

Three screws of the same diameter, the ratio of pitch to diameter being 1.55.

Two large screws mounted on the lateral shafts, having, like the first, the number 1.25 as ratio of pitch to diameter, but having a diameter of 54^{cm}, so that the sum of the areas of the surface described by the extremities of their blades equaled the three corresponding areas of the smaller screws. For the sake of simplicity we will say that the propulsive surface was the same in each case.

Finally, the small lateral screws were put back by themselves and the first group of experiments tried over again, the two pitches being tested turn about. This last formed a series complementary to the first.

"Contrary to what might have been expected, the greatest pitch, although its ratio to diameter was very high, turned out to be the most favorable to speed. This result was due to the fact that the screws mutually influenced each other at high speeds in consequence of their proximity, and this influence, which was scarcely perceptible at about 500 revolutions, was very marked, with the screws of small pitch, when driven at about 150 revolutions more than the above number. The proof of this was forthcoming when the central screw was suppressed in the experiments complementary to the first series. In this case the propellers were more completely independent, and the screw of smaller pitch had the advantage. It was also ascertained that with this pitch an increase of speed was gained when the central screw was suppressed. Further experiments confirmed this result.

"On the other hand, the best of the two sets of three screws above mentioned hardly attained the efficiency of the two large screws. This fact ought to occasion no surprise, for the substitution of the double for the triple system of screws only implied that a propulsive surface, equal in the two cases, was in the latter instance more completely separated from the hull."

The *intermediary series* of experiments consisted of trials with three screws, so arranged that the lateral propellers were mounted in advance of their supports, and 33^{cm} in front of the position assigned the central one.

"The propellers being then at a greater distance from one another, the effect of an exaggerated speed of rotation made itself less felt, as indeed might have been expected, and the advantage remained with the screws of small pitch.

"It may then be concluded that, whenever the independence of the propellers is sufficiently provided for, the pitch, whose ratio to diameter is 1.25, should be preferred to a more rapid one, as well for systems of three as of two screws."

In the *second series* of experiments the lateral shafts were brought nearer together by 65^{mm}, while still remaining 33^{cm} in advance of the central screw, so that they were completely covered by the exterior contour of the hull. The supports of the shafts were then placed in front of the screws in the usual way.

"The results differ but little from those obtained in the *intermediate series*. However, in analyzing the results, it is to be remarked that at low speeds the latter position is less advantageous, which tends to prove that, in this case, it is the injurious effect of the proximity of the hull which affects the result. At high speed, on the contrary, the latter arrangement proved to be superior, which result must be attributed to the better relative position of the supports. It is easy to understand that this influence predominates at high speed, since the resistances to progression increase at a much more rapid rate than the speed.

"If we reflect that rudders have much less influence when placed before the screw than when behind it, it will be understood that a body in the neighborhood of the screw is especially prejudicial when it acts as an obstacle to the water which the latter projects."

M. Marchal then describes an experiment he made with a small screw revolving in air, and its effect upon the flame of a lighted candle when held at different points within its influence.

He found that "the screw draws air from all points situated in front of a transverse plane passing through the extremity of its blades, and even from a little behind this plane; it then projects this air in a truncated cone, or more correctly a sort of truncated pear, the small base of which is a circle equal to the diameter of the screw, the generating line being inclined at the outside at an angle of 30 degrees at the start. Properly speaking, the surface generated by this line is a zone of unstable equilibrium, within which the flame is repelled, and on the outside of which the tendency to attraction is made manifest.

"It is important to remark that in this case the screw turns in a fixed position, and if we had to do with a vessel in motion the truncated cone would be drawn out so as to approach the shape of a cylinder. I had the opportunity of verifying this induction in a voyage in the tropics during nights when the sea was phosphorescent. The mass of water thrown back by the screw appeared to be inclosed in a cylinder of the same diameter as the propeller, and had the appearance of a sort of luminous spiral fagot, which I could not better describe than by comparing it to a cable of very slow pitch which continually untwisted itself in proportion as its length increased.

"From this observation it results that a bracket placed in front of the screw allows the fluid to reach the latter from a multitude of points, while if placed behind it intercepts a slice of a truncated cone proportional to its own section.

"The facts also show why there is an object in putting the screws solely behind the vessel, and not simultaneously in front and behind.

* * * * * * *

"In short, one may conclude from this experiment that if the three screws interfere with each other at great speeds, when they are placed in the same transverse plane, it is not because they send water to each other in consequence of the phenomenon designated by the name *dispersion*, but because they dispute with each other for the possession of the water which they draw upon."

M. Marchal sums up the result of the experiments as follows:

"With vessels of the form of the *Carpe* three screws are, from the point of view of speed, very nearly equivalent to two screws of the same propulsive surface, and immersed to the same depth, when the most favorable position is chosen for each system.

"Twin screws, when under the above-mentioned conditions of surface and immersion, occupy in all cases positions which are disadvantageous in their relation to the requirements of war, and which are difficult of access in roadsteads and ports; on the other hand, it is possible to find for three screws positions which are without inconvenience from the point of view both of fighting and navigation.

"In short, a circumstance which is most interesting in the case of three propellers is, that of all the positions that have been tested those which are best sheltered by the hull are also those most favorable to speed."

"In a word, for a vessel of similar form to the *Carpe*, the best plan appears to be to employ a system of three screws placed like those in the second series of experiments, and having a ratio of pitch to diameter differing but little from that ordinarily in use for vessels having single or twin screws."

In the Italian navy there are three torpedo-cruisers, the *Tripoli*, the *Montebello*, and the *Monzambano*, fitted with three screws, as shown in Fig. 13.

The results of some trials made with the *Tripoli* are given in the following table:

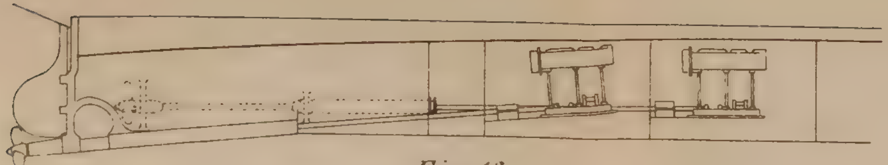
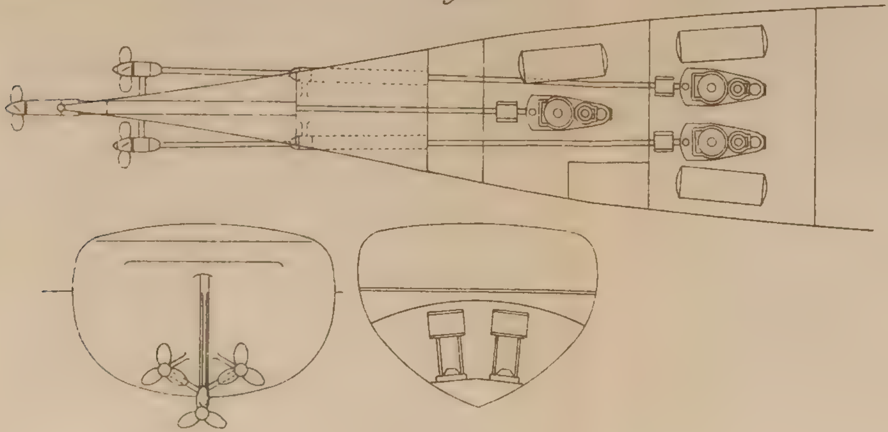


Fig. 13.



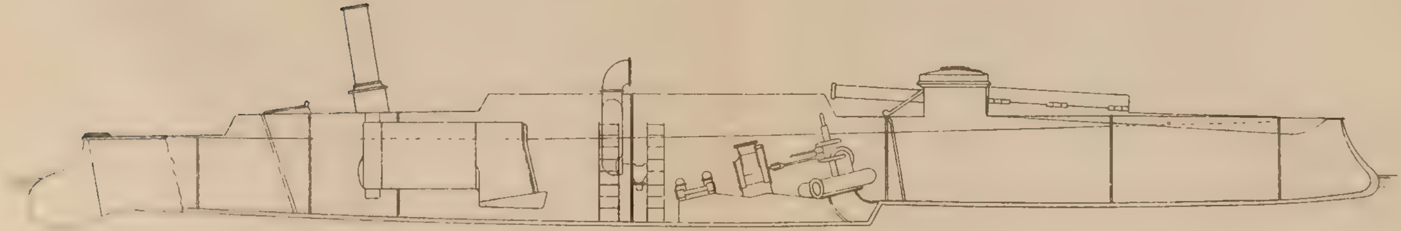


Fig. 14.

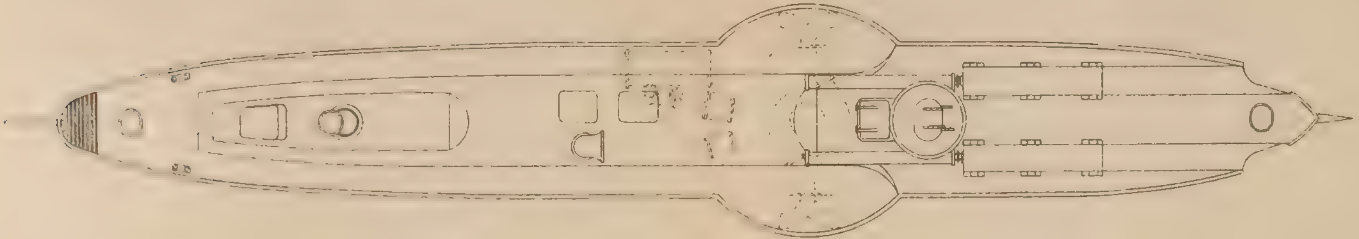


Table showing results of trials made with one, two, and three screws in the royal Italian torpedo-cruiser Tripoli.

Number of screws used.	Diameter of screw.	Pitch.	Surface.	Mean revolutions per minute.	I. H. P. (mean).	Speed (mean).	Slip.	Draught (mean).	Displacement.
	Ft. in.	*Ft. in.*	*Sq. ft.*				*Per ct.*	*Ft. in.*	*Tons.*
1	5 3	6 1¼	7.15	356	1030	14.55	.32	9 10¾	770
2	5 1	6 1¼	6.52	383	2076	$18\frac{2}{6}$	18.6	10 2⅜	802
3	5 9	7 1½	7.57	297	3016	19.8	5.25	10 5½	831

Length of vessel, 230 feet; breadth, 26 feet.

In speaking of the above trials Mr. F. C. Marshall says: "They are, perhaps, not strictly comparable, as, owing to local circumstances, they were each made with somewhat different screws; the trials of one and two propellers being made with the same screws, only slightly reduced in diameter for the two-screw trial, while the three-screw trial was made with propellers of larger diameter and greater pitch; and, moreover, as we have not corresponding records of the powers required to drive the vessel the same speed with all three screws, we can not estimate precisely the propulsive efficiency of one or two screws as compared with the three screws, but it is interesting to note that the efficiency of the single screw is by no means so small as might have been supposed, considering its small size."

In the absence of more detailed information concerning the performance of these vessels, it is possibly unwise to venture an opinion upon them; but from what has been said before as regards the position of the screw, it would appear that that given the central one is extremely disadvantageous. This applies as well to the original as to the final posision of the central screw.

Among the latest additions to the French navy is the *Dupuy-de-Lôme*, a vessel of 6,296 tons displacement, which is to be propelled by three screws. The central screw occupies the position usually assigned to single screws, while the other two are both forward and above it. At the present writing this vessel has not been launched.

SEXTUPLE SCREWS.

The Russian circular armor-clads, or *Popoffkas* as they are commonly called, are fitted with six screws, each screw driven by a separate engine.

The larger of the two, the *Vice-Admiral Popoff*, is of 3,590 tons displacement, and 3,066 I. H. P. The speed obtained is 6 knots.

The information concerning the performance of this vessel is meagre, and as the shape of the hull differs so materially from the form best adapted for high speed, the little that is known of her performance can be looked upon only as so much additional information to the general subject, and not as bearing directly upon the application of multiple screws to vessels of the common type.

HYDRAULIC PROPULSION.

As early as 1661 patents for hydraulic propulsion were taken out by Toogood and Hayes. In 1853 a vessel, fitted with Ruthven's propeller, was built in Prussia for commercial purposes, and a floating fire engine, upon the advice of Brunel, was propelled by the reaction of her jets. In 1866 the *Nautilus*, 115 feet long, attained a speed of 8.32 knots with 127 I. H. P. She had a 7-foot turbine which drew water through the bottom forward and discharged it through two nozzles at the sides, just above the water-line. The area of each nozzle was 78.54 square inches. The *Waterwitch* was 162 feet long, 32 feet beam, and 1,161 tons displacement. There were two discharge nozzles at the sides, level with the water, the mean diameter of each being 24 inches. The speed attained was 9.3 knots.

The *Waterwitch* was tried against a sister ship, the *Viper*, fitted with a screw-propeller, and the results of the trial are given in the following table, taken from a paper by Mr. S. W. Barnaby:

	Date.	Length.		Beam.		Maximum. draught.		Displacement.	I. H. P.
		Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Tons.*	
H. M. S. Viper	1867	162	0	32	0	11	10	1,180.00	696
H. M. S. Waterwitch	1867	162	0	32	0	11	2	1,161.00	760
Swedish screw	1878	58	0	10	9	4	3	20.00	90
Swedish hydraulic	1878	58	0	10	9	4	2	21.00	78
Thornycroft screw	1883	63	0	7	6	3	8½	12.89	170
Thornycroft hydraulic	1883	66	4	7	6	2	6	14.40	167

	Date.	Speed per hour.	Midship section.	$\frac{V^3 D^{\frac{2}{3}}}{I.\ H.\ P.}$	Propellers.	Number of revolutions per minute.
		Knots.	*Sq. ft.*			
H. M. S. Viper	1867	9.58	337.0	141.4	2 screws.	110
H. M. S. Waterwitch	1867	9.30	336.0	116.9	1 turbine.	40
Swedish screw	1878	10.00	25.0	82.0	2 screws.	250
Swedish hydraulic	1878	8.12	25.0	52.5	2 turbines.	384
Thornycroft screw	1883	17.30	11.9	169.0	1 screw.	636
Thornycroft hydraulic	1883	12.60	13.4	72.0	1 turbine.	428

In 1878 the Swedish Government built an hydraulic torpedo-boat, the trials of which are included in the above table.

Mr. Barnaby gives the following as the advantages claimed by the advocates of the system:

"No impediment to speed under sail; no racing due to pitching; no vibration; power of reversing motion in the hands of the officer on deck; full engine power for manœuvring; vessel capable of being double-ended, and power of ramming much increased. The propeller is not liable to damage from running aground, and can not be fouled by floating obstructions; it is favorable for light draught, and the large pumping power is available for keeping down leaks.

Against these he places the following:

" First and foremost is the difficulty of utilizing the full energy of the feed-water, or the velocity of the water entering the propeller. Secondly, every particle of water acted on must be carried in the ship. Thirdly, the loss by friction of the water in the passages. Fourthly, the loss by bends in the pipe, which can only be reduced by increasing the losses from the second and third causes, namely, the weight of water carried and the friction of the passages."

In 1881 the Admiralty ordered a number of second-class torpedo-boats from Messrs. J. I. Thornycroft & Co. It was stipulated that one of these was to be driven by a turbine propeller.

Engineering says: " In ordering the torpedo-boat above referred to the chief object the Admiralty authorities had in view was to arrive at a true estimate of the value of hydraulic propulsion to such boats. For this reason it was originally intended that the boat should be as nearly as possible like one of the screw boats of the same class, in order that the performance of the two might be compared. It was, however, found necessary to depart from this principle to a certain extent for the following reasons: The number of revolutions made by the engines of the screw boat is about 630 per minute, a speed which was considered much too high for the turbine, the revolutions of which were fixed at 400 per minute. This necessitated larger cylinders in order that the same power might be developed, and the weight of the engines was therefore more. The total weights of machinery, including water in the boiler, for the hydraulic and screw boats, respectively, were 5.56 tons and 4.87 tons. If the same dimensions had been retained for both vessels that having the heavier machinery would have been unduly handicapped, and an additional length of 16 inches was therefore given to the hydraulic boat. No doubt these alterations tended to equalize the results and allow a truer comparison to be made between the efficiency of the machinery in the respective vessels. The difference in length tells slightly in favor of the longer boat. The engines of the screw boat had cylinders 8¼ inches and 13½ inches in diameter and 8 inches length of stroke; while the turbine propeller was driven by a pair of 8½ inch and 14½ inch engines having a stroke of 12 inches. Although there was no reversing gear in the latter they were 1.9 tons heavier than the former."

Mr. Barnaby gives as causes of loss of work in propellers of different kinds, irrespective of friction, the following:

(1) Suddenness of change from velocity of feed to velocity of discharge.

(2) Transverse motion impressed on the water.

(3) Waste of energy of the feed water.

"The uniform-pitch screw and the ordinary paddle-wheel suffer from the first cause, whilst those which more or less avoid it are the gaining-pitch screw, certain forms of feathering paddles, Ruthven's form of centrifugal pump, and, probably best of all, the oar. Ordinary screw propellers, radial paddle-wheels, and oars lose from the second cause. This loss is greatly reduced in the guide-blade screw propeller and is entirely avoided in the turbine propeller. The third cause of loss is only experienced in the jet propeller as it has been previously used, and it is from this, principally, that its inefficiency results."

On this account every effort was made in the boat built by Messrs. Thornycroft (see Fig. 14) to utilize as much as possible the velocity of the feed water.

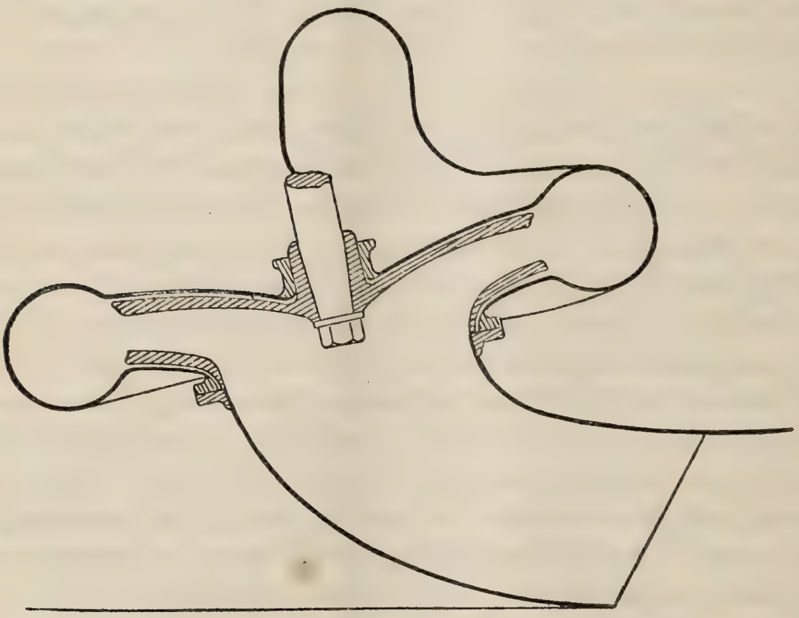


Fig. 15.

"Fig. 15 shows the manner in which the turbine was placed in the boat. There is a sudden break just forward of the pump, the bottom of the boat at that point being formed into a large scoop, a cross section of which is shown in Fig. 16. The passage rises by a gentle inclination to the inlet of the pump, which is placed at an angle so as to reduce the change of direction as much as possible. The velocity of the water causes it to rise in the scoop

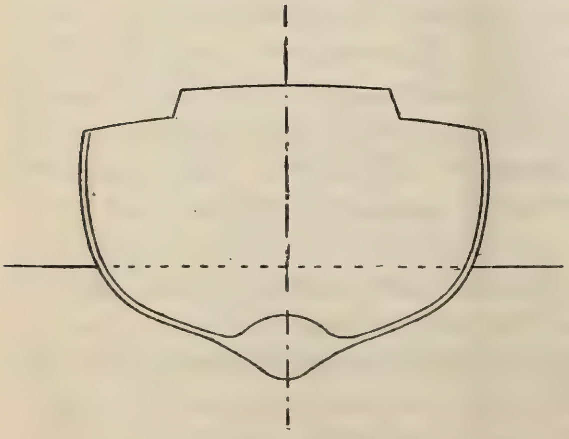


Fig. 16

and the vanes of the pump are shaped to pick up the water without shock, and gradually to accelerate it to the speed of discharge, when it is got overboard as quickly as possible.

"The nozzles in this boat are each 9 inches in diameter, and are formed of pieces of copper pipe bent to a radius of 18 inches. They are placed, as may be seen by the general view, just above the water line, and can be turned so as to direct the jets either ahead or astern by means of handles in the conning tower.

"The discharge orifices for the jet were, as in the *Waterwitch*, above the water line, but at one time it was thought that something might be gained by placing them below the water. Mr. Thornycroft was of opinion that something might be gained by induced currents set up by the discharged water, and experiments were made to elucidate this theory."

The result of these experiments showed that the resistance of the nozzles towed through the water far outweighed the loss by raising the water the extra height necessary to discharge it above water.

"One of the great advantages claimed by the advocates of hydraulic propulsion for vessels to be used for purposes of warfare has been the extraordinary power that would be available for freeing the vessel from water. Mr. Barnaby, however, rather upsets preconceived notions on this score, and as a matter of fact it was not found advisable in the torpedo-boat in question to make any provision for converting the hydraulic propeller into a gigantic bilge pump. A centrifugal pump will not work unless fully charged, and the supply of water necessary in the case of the propeller in question is so enormous in proportion to the size of the boat that large and complicated valves become needful for closing the inlet and throwing the pump into communication with the bilge, and also to supplement the bilge water from outside, as the former becomes insufficient to feed the pump. The pump delivers an amount of water equal to the displacement of the boat in fifteen seconds, and although the appliances required might possibly have been fitted, yet they would have involved so much additional weight that it was determined to forego their use rather than sacrifice speed, which is the first necessity of torpedo warfare.

"The form of inlet adopted with this boat is obviously a bad one for going astern, and so what has always been considered one of the strong points of the hydraulic system, *i. e.*, equal facility in going ahead or astern, is lost. But, as Mr. Barnaby points out, anything designed for locomotion in more than one direction may generally be adapted to give a better result when moving in one particular direction rather than in any other. What is wanted in a torpedo boat is more especially high speed and quick turning, but considering that Mr. Thornycroft claims to have raised the efficiency of the jet from 0.50 to 0.71 by this particular form of inlet, he would, no doubt, have considered it desirable to adopt it and sacrifice sternway powers, whatever class of vessel he might have had to design."

"The performance of the boat is given in the following table, the speed being at the rate of 12.65 knots per hour. The efficiency of the pump and jet combined, *i. e.*, useful work in the jet divided by the effective horse-power, it will be seen was 0.33, and the total efficiency, *i. e.*, useful work in jet divided by indicated horse-power, 0.254."

	Diameter of turbine.	Area of inlet.	Combined area of discharge.	Midship section.	Velocity of discharge.	Water discharged.	Efficiency of pump and jet.	Total efficiency.
				Area of discharge.				
	Ft. in.	*Sq. ft.*	*Sq. ft.*		*Ft. per sec.*	*Lbs. per sec.*		
H. M. S. Waterwitch...	14 0	28.25	6.280	53.5	29.0	11.650	0.234	0.180
Swedish hydraulic.....	1 11½	1.62	0.864	30.5	28.0	1.510	0.277	0.214
Thornycroft hydraulic.	2 6	1.52	0.951	14.1	37.2	2.210	0.330	0.254

The position of the inlet appears to be a matter of considerable importance.

"In the Swedish boat the feed was taken in at a point considerably forward of the pumps, of which there were two, and was conveyed by suitable passages. Afterwards an opening was made in the bottom of the boat almost immediately below the pump and the water was brought up much in the same way as in the Thornycroft boat, excepting of course there was not the scoop-like action from the break in the hull. By this means the speed was raised from 7.87 knots to 8.12 knots. It is interesting here to note that the *Waterwitch* was altered by Sir George Elliot when he was Admiral Superintendent at Portsmouth, in a very similar way, the result being an additional half-knot in speed."

"The different forms of pump used in the *Waterwitch*, Swedish boat, and Thornycroft are shown in Figs. 17, 18, and 19 respectively, while the arrangement of the Thornycroft pump in the boat is shown by Fig. 20, the means by which the motion of the boat is reversed being shown at P."

"In conclusion the author points out that one of the greatest obstacles to the success of the jet propeller, namely, the loss of energy of the feedwater, has been overcome by adapting the bottom of the boat in the manner described, Mr. Thornycroft having raised the efficiency of the jet from .50 to .71. Forty-six per cent., however, seems to Mr. Barnaby a very low efficiency for the pump, and he thinks it possible that an efficiency of .70 per cent. may yet be reached. In this case the total efficiency would be 0.385, and a speed of 15 knots would be reached."

"At present, however, the case stands thus: In the screw-boat the efficiencies are, engine, 0.77; screw-propeller, 0.65; total, 0.5. In the hydraulic boat, engine, 0.77; jet propeller, 0.75; pump, 0.46; total, 0.254."

Mr. Barnaby sums the whole matter up as follows: "The jet as a propeller may be taken as little better than a screw, but the loss in the pump is a dead loss, and represents about half the power. In other words, before a hydraulically-propelled boat can be made to compare favorably with one driven by a screw, the pump producing the jet must work without loss."

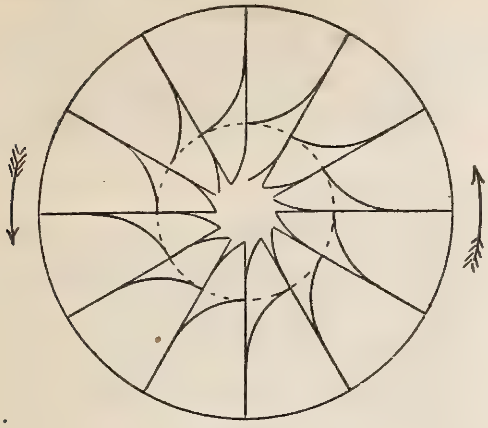


Fig. 17.

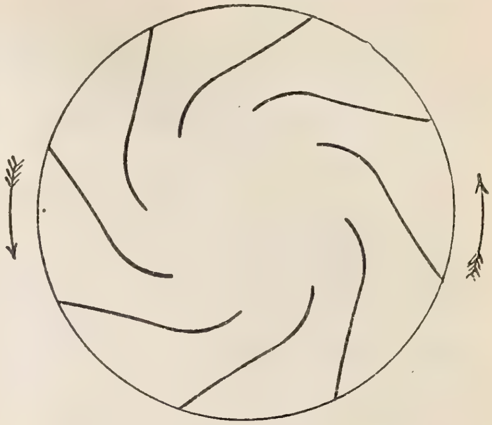


Fig. 19.

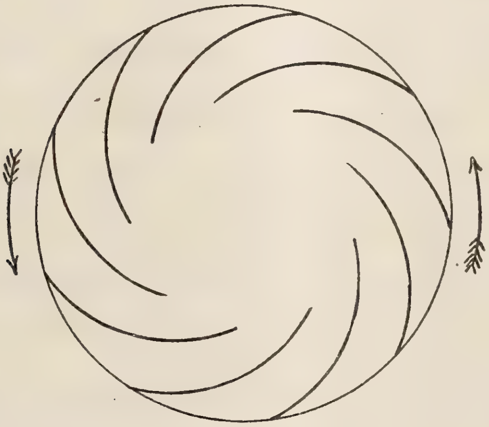


Fig. 18.

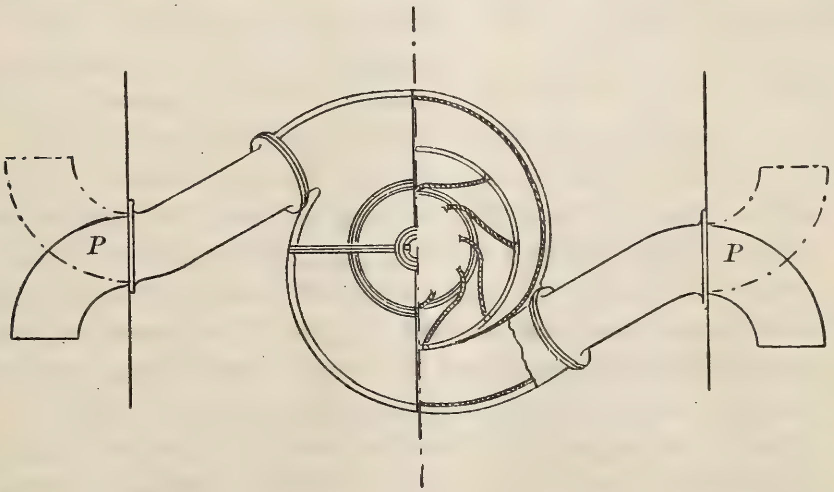


Fig. 20.

FLEISCHER'S HYDROMOTOR.

Shortly before the trials of the Thornycroft torpedo-boat, Dr. E. Fleischer perfected his invention for driving boats by hydraulic power.

This machine was fitted to a small vessel of 105 tons called the *Hydromotor*, which was 110 feet long by 17 feet beam, with a draught of 6 feet to 6 feet 6 inches, and which made a successful voyage from Kiel to Copenhagen and back.

The following is taken from The Marine Engineer:

"The apparatus consisted of two reservoir cylinders, *ll*, each furnished with a large pipe, *g*, leading from the bottom of the cylinder to the nozzle *n* outside the vessel (see Fig. 21). Each cylinder was provided with a float, *f*, of nearly the same diameter as the cylinder. At *d* and *k* are respectively the steam inlet and the exhaust valves, the latter opening to a pipe which conducts the exhaust steam to the surface condenser *m*. At *p* is a valve which during the exhaust stroke allows water to flow through the surface condenser to the working cylinder. The steam inlet and exhaust valves just mentioned are worked by means of a rod fixed to the float in the cylinder, there being provided at the top of this rod feathers which work in a grooved bonnet or guide fixed on the top of the cylinder. A second movable bonnet with a curved groove permitting a semi-rotary motion is fitted over the first, and to this upper bonnet are fitted disks or cams which operate the steam and exhaust valves, and effect the cut-off at any desired part of the stroke."

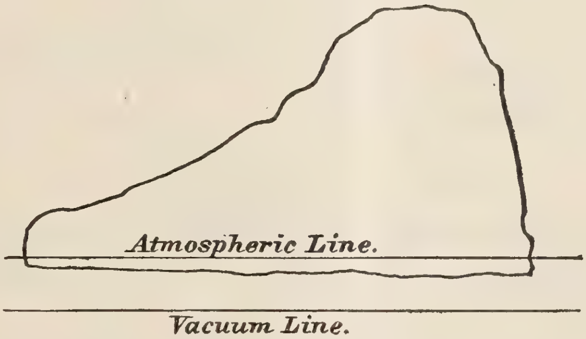
The action of the apparatus is as follows:

"Confining our attention to one of the reservoir cylinders, let us suppose that it is full of water, and the float consequently at the top. In reaching this position the float will have opened the steam valve, and the steam entering the cylinder will press down the float and eject the water beneath it at a great velocity through the nozzle *n*. The float will thus descend until at a certain portion of its stroke the rod above mentioned will close the steam valve, the expansion of the inclosed steam being then utilized in completing the down stroke and ejecting the rest of the water. Just as it reaches the bottom of its travel the float opens the exhaust valve, when the steam rushes into the condenser, and a partial vacuum being formed in the reservoir cylinder the water rushes in partly through the nozzle *n*, but principally through the suction valve *p*, thus raising the float and bringing it again to the top of the cylinder ready for the same cycle of operation to be performed. In the *Hydromotor* there are, as shown in Fig. 21, two reservoir cylinders which perform alternate strokes. In larger vessels the number of reservoir cylinders may be multiplied to any desired extent."

"If it should be desired to drive the vessel astern, all that is necessary is to admit steam to the top of a small vertical cylinder shown fixed by the side of the pipe *g*. The steam thus admitted will cause the piston of the small cylinder to descend, thus sliding down a sluice door in front of the nozzle *n*, and at the same time through the arrangement of levers and links, shown by dotted lines, opening a valve which allows the water in the reservoir cylinder to be ejected through the passage *i*.

"The loss of steam by internal condensation in the cylinders is, as the indicator diagram shows, very small, because a heated surface of water leads heat downward but very slowly. Besides, the cylinders are lined with lignum-vitæ, which has a low specific heat and is a bad heat conductor.

"It is evident that nearly the whole steam-power may be utilized most directly in the working stroke, and the full value of the vacuum may be realized by placing as high a working chamber as possible; the velocity of the jet will be thus increased by the column of water drawn in by the vacuum. The diagram we publish shows very satisfactorily what takes place in the working stroke, and looks like a fair engine diagram.



"The following tabular comparison of the results obtained from the *Hydromotor*, compared with the *Waterwitch* and *Rival* (turbine ships), at once gives the leading place to the *Hydromotor*:

Name of vessel.	Displacement in tons.	Area of midship section.	Speed attained.	Description of machinery.	Indicated horse-power.	Coal consumption per hour.
		Sq. ft.	*Knots.*			*Pounds.*
Waterwitch	1,279	....	9.3	Engine driving centrifugal pump.	760	....
Rival	*170	91	7	......do	292	832
Hydromotor	105	61	9	Fleischer's patent hydromotor.	100	255

Name of vessel.	Area of discharge opening.	Velocity of discharge of water in feet per second.	Water discharged per minute.	Horse-power accounted for in the water discharged.	Loss.
	Sq. ft.	*Feet.*	*Cub. ft.*	*H. P.*	*Per cent.*
Waterwitch	5.33	30	9,000	267	64.9
Rival	3.63	23	5,000	77	73.7
Hydromotor	0.29	66	700	89	11

*About.

"The great point of value to be noticed from these results is that the loss by transferring the steam-power to the water jet is only 11 per cent. in the case of the *Hydromotor*, whilst in the only other test cases of hydraulic propulsion the margin of loss has been 64.9 per cent. and 73.7 per cent.

"Hydraulic propulsion has thus, by Fleischer's invention, been placed at least on a par as regards economy with the best results of screw propulsion. The benefits resulting from jet propulsion also increase with the speed, so that for the high speeds the advantages of economy of jet propulsion will be still greater than can be at present anticipated.

"A further great advantage of the hydromotor is, quite apart from its wonderful simplicity, that all its power can be utilized to keep the vessel clear of water in case of a leak. The dangers of breaking shafts or fouling propellers are all obviated, and a general break-down might be considered impossible.

"The vessel fitted with a hydromotor is particularly well under control, as the driving power can be reversed from the captain's bridge without stopping the apparatus."

MAGINOT'S HYDROMOTOR.

Following the trials of the Thornycroft torpedo-boat in 1882 came the trial by the French Government of the system invented by M. Maginot.

The following on the subject is part of an article which appeared in the Revue Industrielle of Paris:

"The *Nautilus* was the boat used in the experiments. It had the following dimensions: Length, 46 feet, and width amidships, 6 feet. The mean draught was 1¾ feet. The Maginot pump is 23 inches in diameter at its widest part. Suction is effected through a tube, taking water from beneath the keel nearly amidships. The water coming from this pump is forced into a sheet-copper pipe, terminating in a nozzle 8½ inches in diameter, ejecting under water at the stern of the boat. Diagonal tubes throwing water forward serve to back the ship, and tubes at right angles serve to turn her in either direction. The shaft of the engine is actuated directly by a vertical single-cylinder engine 8 inches in diameter and 6-inch stroke." (See Fig. 22.)

The usual advantages of hydraulic propulsion are claimed in connection with the *Nautilus*, and in addition to those previously mentioned it is stated:

"All vibration will be suppressed. The boat will be able to run at any speed under good conditions, while the screw works well only when the speed of the vessel corresponds to its pitch."

No data of the trial are given, but we are told that "the speed of the *Nautilus* was 8 miles an hour, and she made a complete stoppage in forty-five seconds at the end of a run of about 6 miles. If the *Nautilus* did not make very great speed during the experiments it was

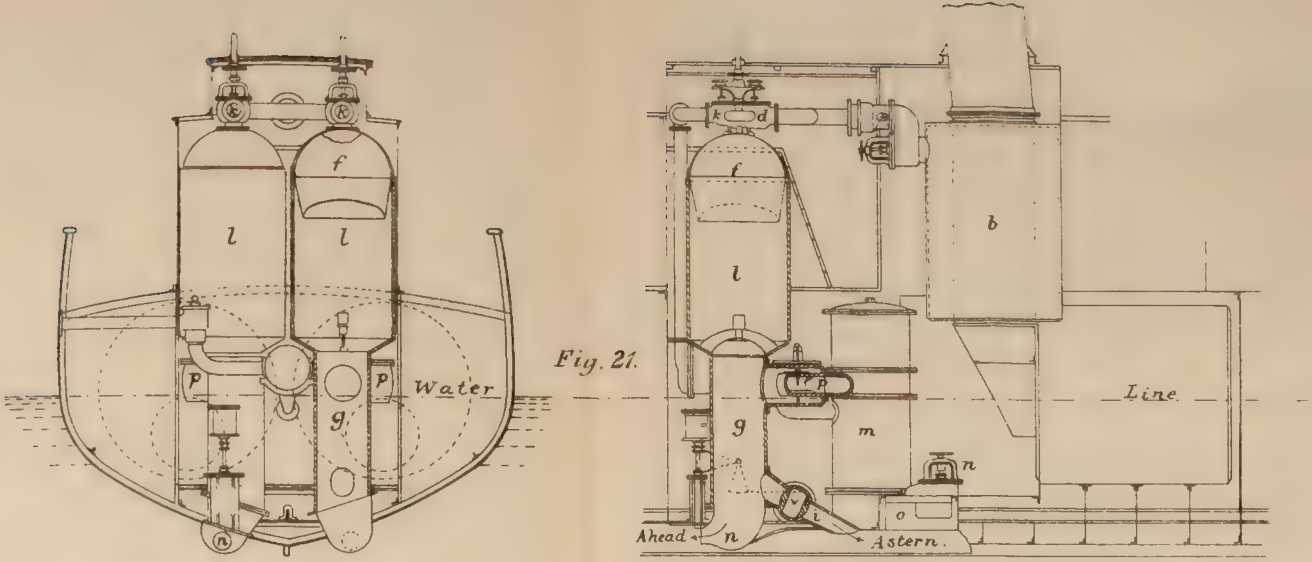


Fig. 21.

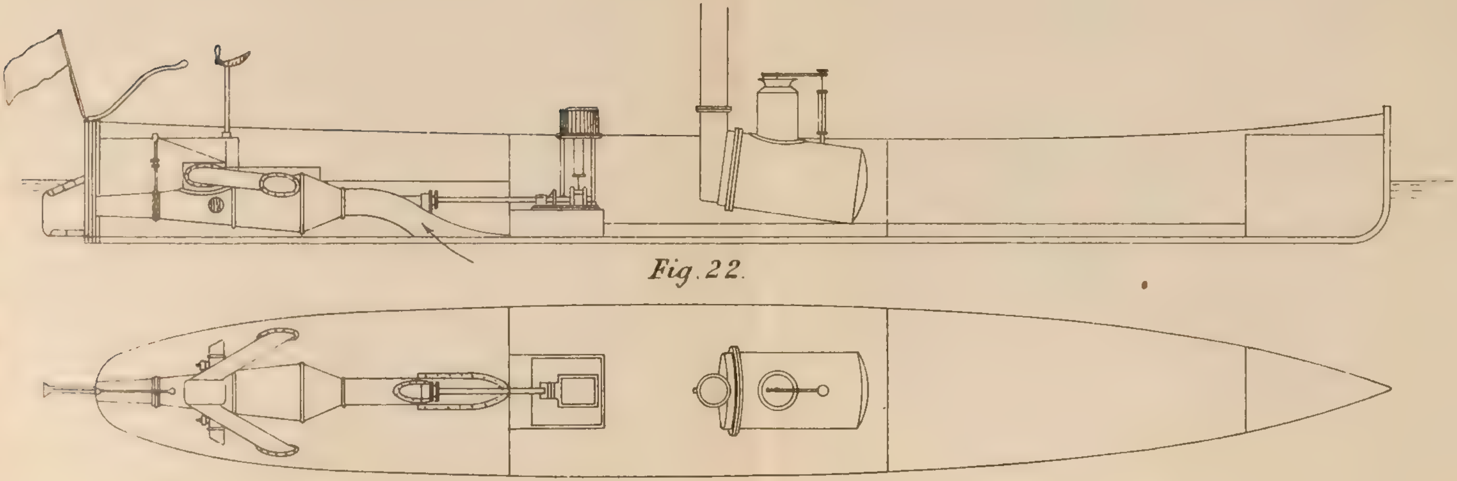


Fig. 22.

VIII.

ELECTRICITY FOR NAVAL PURPOSES.

[This chapter, chiefly prepared by the assistants of the Naval Inspector of Electric Lighting, Bureau of Navigation, Navy Department, is divided into four parts:

1. Incandescent Electric Light Installations of the past year for United States ships.
2. Development of the Insulation of Electric Conductors for Naval Use.
3. Uses of Electricity in the Navy.
4. Remarks by the Naval Inspector of Electric Lighting.

ED.]

1.

INCANDESCENT ELECTRIC LIGHT INSTALLATIONS OF THE PAST YEAR FOR UNITED STATES SHIPS.

By Lieut. T. E. DE WITT VEEDER, U. S. Navy.

Many of the difficulties that have been experienced in electric-light installations generally have arisen from the use of inferior materials, the employment of inferior workmen, and, in consequence, inferior workmanship, and to the fact that there have been few, if any, conditions imposed by law looking to the security of the public or the efficiency of the service. The insurance companies for a long time followed—rather than led—the electric-light companies, and even to-day it is not believed that the American underwriters have any special regulations governing the installation of the electric light on board of ships.

All of the new ships have been provided for either in the contracts with the builders or by special appropriation, and the Navy Department is introducing this benefit, so important to the efficiency, health, and comfort of all, into such of the old ships as promise a life-time sufficien to justify the expenditure and a limited appropriation will permit. During the year the installations of the *Yorktown* and *Charleston* have been completed and the *Baltimore* and *Pensacola* well advanced, the work on the latter ship being done from the current appropriation of the Bureau of Navigation, while the others come under the appropriations in lump for the new ships. The contracts for these installations were made with the Edison Company, which likewise has the contracts for the *Philadelphia*, *San Francisco*, *Concord*, and *Bennington*. The last two, with the *Yorktown*, are supplied with two generating sets, duplicates, while the *Pensacola* has but one, and the *Baltimore*, *Philadelphia*, *Charleston*, and *San Francisco* are to have three each, all of the same pattern.

Congress has also appropriated for electric-light installations for the *Petrel*, *Vesuvius*, *Puritan*, *Monadnock*, *Miantonomoh*, *Terror* and *Amphitrite*, as well as for the receiving-ship *Vermont*. Those for the *Petrel*, *Vesuvius*, and *Vermont* should be completed within the present year, and work on the remainder will be commenced as soon as the ships are in condition to receive them.

Much progress has been made in efficiency and security in the ships installed during the past year, the principal of the changes being the adoption of lower-speed machines directly coupled to the engine by means of a flexible coupling, thus avoiding the use of a belt, which is not suited to the conditions existing on shipboard. (Fig. 1.) While the speed of the machines has been reduced to 400 turns, their output per pound of weight has been increased, and they have further been improved in the insulation of their coils and the reduction to a practicable minimum of the heating of the same. The engines used are two-cylinder, instead of one-cylinder, as heretofore, giving a better balance and more perfect regulation, the specifications for the engines requiring as follows:

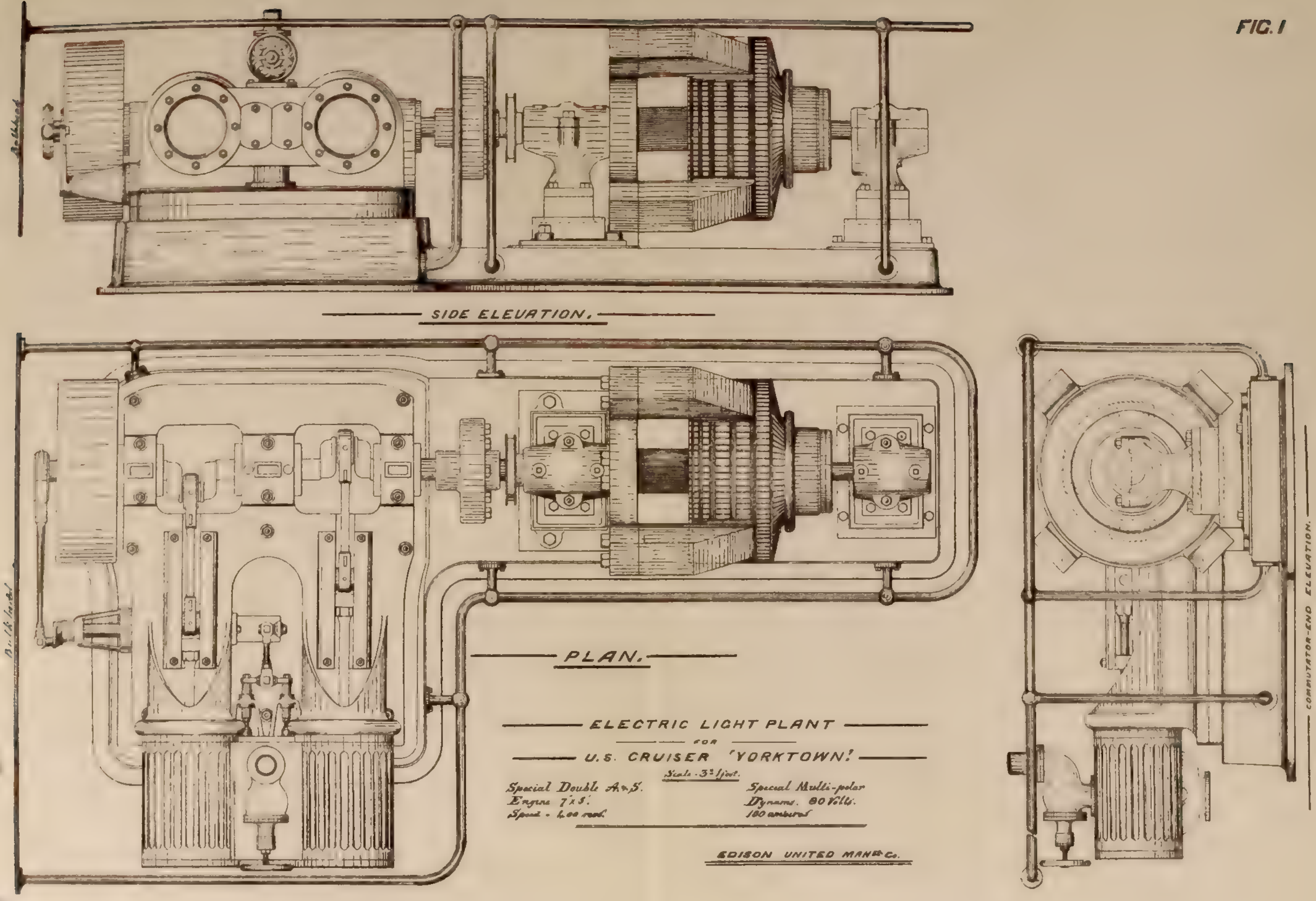
(1) The engines must be of the best materials and workmanship, and as light as possible consistent with the necessary strength. The cylinders and other parts subjected to steam pressure must successfully withstand a water-pressure test of 260 pounds per square inch. They must be able to bear without injury the removal of the entire load by suddenly breaking the circuit of the dynamo.

(2) The engines must be direct-acting, and either horizontal or vertical. Each must be directly connected to the armature shaft of its corresponding dynamo by means of a suitable flexible coupling, and capable of driving it at a speed of four hundred revolutions per minute when the dynamo is generating the maximum output required.

(3) Initial steam pressure, 80 pounds; cut off, one-fourth; exhaust, either atmospheric or vacuum. The engines must govern automatically and meet the following conditions: A variation of 2 per cent. only in the revolutions will be allowed—(*a*) on any change of load between total output and 20 per cent. of the same; (*b*) on any change of steam pressure between 60 and 100 pounds while exhausting into the atmosphere. A variation of 5 per cent. only will be allowed—(*a*) on any change between full and no load; (*b*) exhausting either into the atmosphere or a vacuum with steam pressure at 80 pounds.

(4) The engines must be fitted with the most efficient kind of lubricating appara-

FIG. 1



ELECTRIC LIGHT PLANT
FOR
U.S. CRUISER 'YORKTOWN.'

Scale - 3" 1 foot.

Special Double A. & S.
Engine 7" x 5".
Speed - 400 revol.

Special Multi-polar
Dynamo. 80 Volts.
100 amperes

EDISON UNITED MANFG. Co.

tus, with positive-motion engine-counters of an approved type, and with efficient appliances for ascertaining the indicated horse-power of the engines. The cylinders and valve-chests must be cased with approved non-conducting material and mahogany or other approved covering.

The improved character of the coverings of the conductors, the abolishing of soldered splices with their indifferent and constantly-failing insulation, the substitution of substantial water-tight receptacles for portable plugs for the weak and inefficient ones formerly used, the improvement in the design of the water-tight switch and in the molding used, the introduction of incombustible bases for switches, receptacles, and cut-outs, the supplanting of the wooden switch-board by one of incombustible material, and the installation of fixtures of excellent quality and suitable design, have all helped to render the system more complete by the elimination of faults either foreseen or already developed by experience.

A higher degree of insulation of the conductors when installed, is demanded and obtained, and this can only be brought about by the use of good materials and superior workmanship in doing the wiring. The security from fire and the uninterrupted supply of the current depend upon this work, which is the most expensive part of the installation and requires a considerable time for its performance. The dynamos and engines may be changed in a moment when worn out, or when, from the advance made in the production of generating sets, it may be deemed wise to replace them, but the wiring as a whole, once properly put in, should never require renewal. It is to an appreciation of these facts that is due the improvement made in its character, until the performance now generally accords with the requirements.

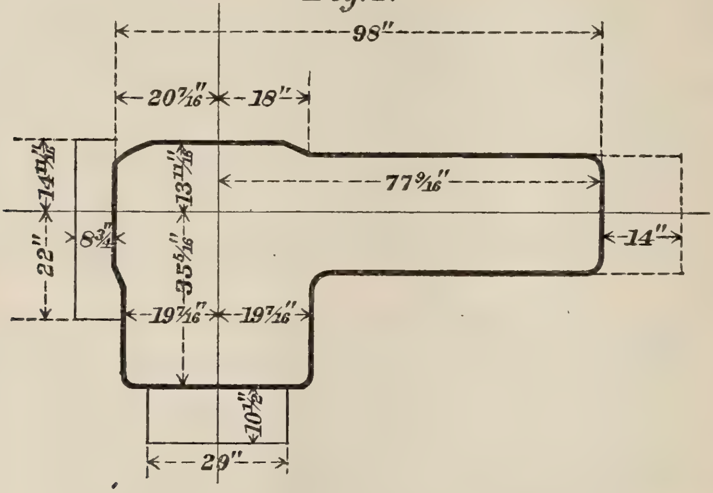
In describing briefly the character of our installations, the dynamo room comes first—its location, the arrangement of its contents, and its ventilation; then, following the circuits from the switch-board, the manner in which they are run, the devices employed, and the different sorts of fixtures assigned to fulfill various offices, will be observed.

The location of the dynamo room should be made with a view to the security of the machines during time of action and to its close proximity to the steam supply; the importance of the first being apparent, while the second requires but little reflection to appreciate the advantages of dry steam and the absence of the disadvantages attendant upon the conducting of large steam pipes to a considerable distance, and through the holds and store-rooms of a ship. The space immediately forward of the forward fire-room satisfies the conditions best. Here enough floor space should be assigned, leaving sufficient head room to afford opportunity for efficient attendance.

The spaces required for generating sets composed of Armington & Sims 7 by 5 inch double engines and Edison compound wound multipolar dynamos as installed in the *Yorktown* and in the *Baltimore*, are indicated in Figs. 2 and 3, the heavy lines showing the outside dimensions of the bed-plates, the additional space in the direction of the length of the armature allowing for its withdrawal, and the laps over the engine end of the plates allowing for the cylinders and fly-wheel.

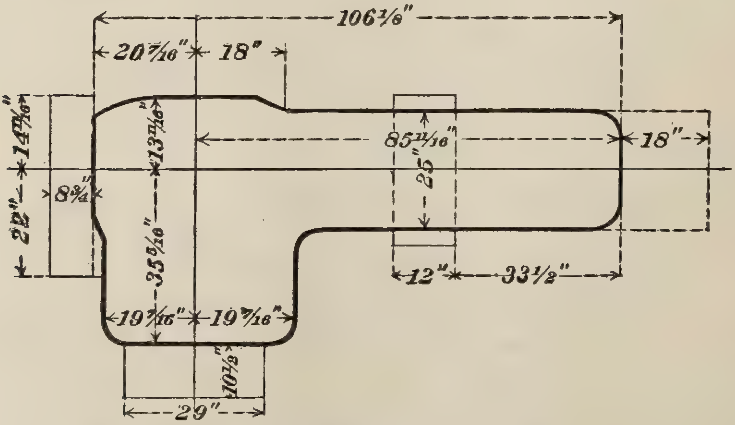
The bed-plates are set upon light steel foundations, built up 9 inches above the deck, and having on top of the steel cover a 2½-inch white-pine floor, which, with a coaming around all sides is covered with sheet lead to receive such part of the drip as may escape from the oil-way running around the bed-plate. Each plate is securely bolted through its flange and the flange of the foundation. A foundation for an Armington & Sims 7 by 5 inch engine and 200 ampère Edison multipolar dynamo is shown in the sketch with dimensions (Fig. 4). This brings the commutators to a convenient height for the adjustment of the brushes and renders the attendance much more convenient.

Fig. 2.



Floor space for 100-Ampere generating set.

Fig. 3.



Floor space for 200-Ampere generating set.

A comparison of the space occupied and the weights of each of the two sets installed would be extremely unfair to that of 100 ampères, since its engine is, owing to an exigency, of exactly the same size as that used with the 200 ampère machines. The weights of each set are as follows:

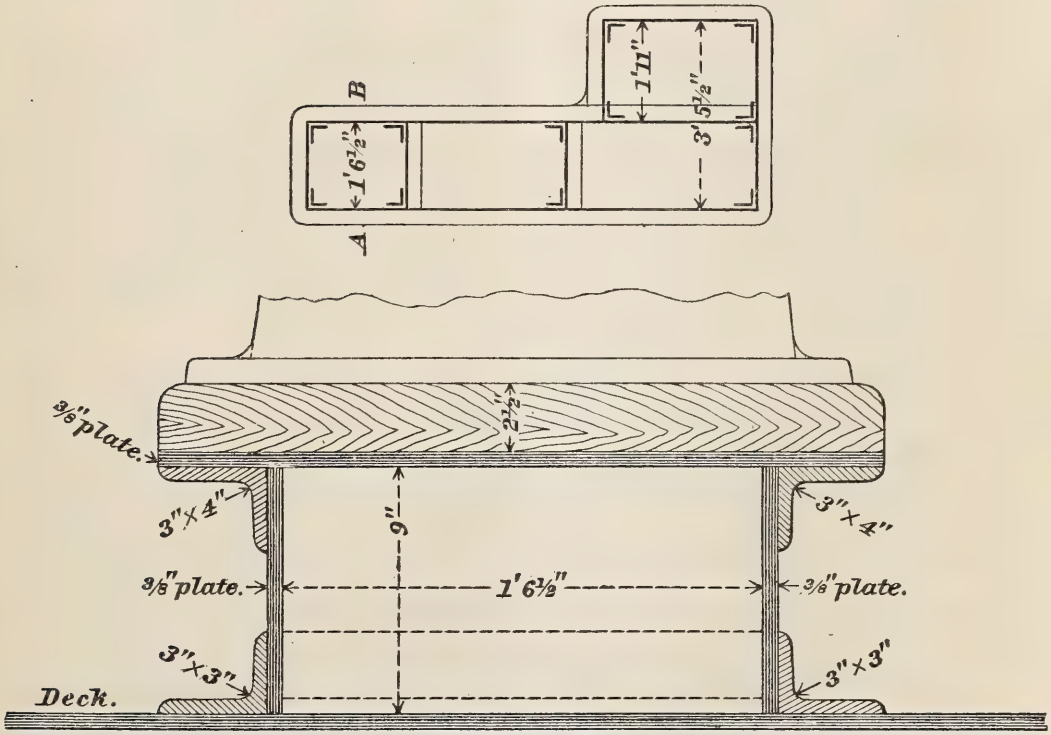
100 ampères.

	Pounds.
Engine (Armington & Sims 7 by 5 inch)	2,230
Dynamo without armature	1,435
Armature	406
Bed-plate	937
Total	5,008

200 ampères.

	Pounds.
Engine (Armington & Sims 7 by 5 inch)	2,230
Dynamo without armature	2,557
Armature	813
Bed-plate	1,143
Total	6,743

Fig. 4.



Section at A–B.
Foundation for 200-Ampere plant.

Comparing the weights of the dynamos, 1,841 pounds and 3,370 pounds, with their outputs shows even then a slight difference in favor of the 200 ampère machine, which might be expected, it giving 4.75 watts per pound to 4.34 watts per pound of the 100-ampère machine.

In addition to the spaces required for setting and operating the several generating sets, sufficient room must be allowed for the switchboard, which if practicable should be arranged so that a person may pass behind it, and having a shelf in front carrying the meters, and with the regulator boxes conveniently placed beneath the shelf; if practicable the steam separator and automatic trap should be located in the dynamo room, and space should further be allowed for oil and waste tanks, and a suitable locker for tools. Preferably the switchboard should be as near as practicable to the commutator ends of the machines. It should be of such dimensions as may be required and conform in shape to the space assigned it. Every part of it is made of incombustible materials, the board being of slate, the cut-out blocks of porcelain, and the switches being entirely of porcelain and metal.

The wiring of a ship is controlled by the considerations of the reduction to a minimum of the fall in electromotive force, the probability of a break in a circuit, and danger from fire; there are other considerations, but these are the most important. The first ships installed were wired in the same manner as were houses, and since it is now an admitted fact that the work then done in the latter was hopelessly bad, it can easily be understood that on shipboard, with salt water penetrating nearly everywhere, it required constant attention to keep the lights in operation.

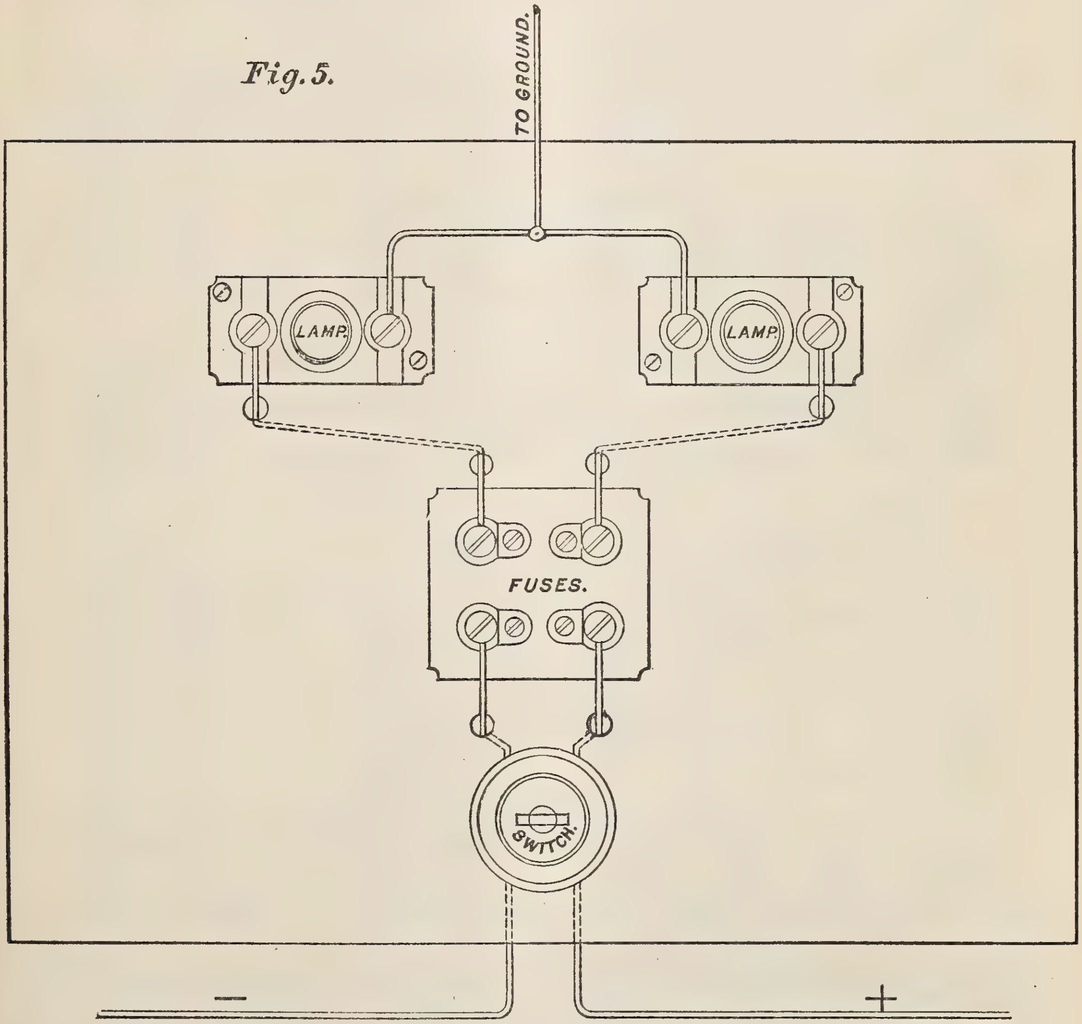
The lights having been assigned, and the sections laid out as best to carry on the ship's duties and conform to the established routine usages of the service, the sections when brought to the switch-board are arranged, as near as may be practicable, so that the total work to be performed may be halved and each half may be fed separately by its own machine; or, if one machine will suffice to perform the duty at any moment, by means of switches any one of the machines may feed into all of the sections. Each section is controlled by a double pole switch and protected by a double pole cut-out.

A ground detector (Fig. 5) of the character shown in the sketch is attached to each half of the switch-board, a difference in the intensity of the lamps indicating a leak.

Every ship is provided with a testing set for measuring insulation resistances, but this requires the ship to be steady to operate it at all satisfactorily, so that ordinarily at sea no measurements could be taken, and reliance would be placed upon the ground detector. The volt and ampère metres are made by Siemens, of London; the specifications requiring that they shall contain no permanent magnets nor depend upon the action of gravity. The regulator boxes are made of slate slabs carrying the coils, with brass standards at the corners. A tachometer is belted to the shaft of each armature, and it is proposed also to install a positive motion engine counter, in the readings of which there can be no mistake. A steam gauge and a vacuum or back-pressure gauge are likewise put in. By means of these various instruments, metres, indicators, gauges, ground detectors, etc., the attendant may intelligently carry on his work and not be compelled to guess at the cause of such difficulties as may occur, and with the natural consequences in such cases.

The steam supply is usually by a branch from the pipe supplying the other auxiliaries of the ship. It should have a reducing valve located at a sufficient distance from the engines to allow a steam space in the pipe and separator equal to at least five times the volume of steam used at a stroke by the engines getting steam through the valve. Trouble has been experienced with these valves, but not since they have been put in in this manner. The separator should be placed as near as practicable to the first branch taking steam from the pipe. At each branch of both steam and exhaust pipes a stop valve is placed for convenience in making repairs. Into the drain from the trap should be carried the drips from the cylinders and a drain from above the engine stop valve; also, if the exhaust piping is carried up, it too should be arranged to be drained before starting up.

Fig. 5.



Ground Detector.

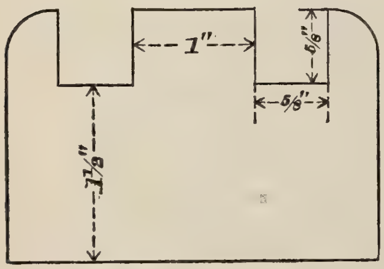
The dynamo room, being below the protective deck and without any natural ventilation, should be thoroughly well ventilated artificially, as well for the good performance of the machines as for the health of the attendants, and for this purpose it is supplied with independent conduits for the exhaust and supply of air and a fan and electric motor, those on the *Yorktown* being connected by a belt. While this latter performs in a fairly satisfactory manner, yet the belt is unnecessary and the arrangement wasteful of space; hence, in the *Baltimore* and other ships it is proposed to wind the armature upon the shaft of the fan. Careful attention to the covering of all steam-piping, cylinders, and valve chests aids in keeping down the temperature.

As before stated, the number of lights, with the location of each and the style of fixture to be employed, is determined from a consideration of the duties of the ship and the manner of carrying them on, which considerations also prevail in the arrangement of the lights into sections. It is furthermore desirable that a section main should not exceed in size a No. 6 B. W. G. wire or its equivalent, as a larger one soon becomes very difficult to work; also, where practicable, it is usual to put the lights on the opposite sides of a deck upon different sections, so as to reduce the probability of total darkness. The sections having been laid out, the sizes of the mains, which are the same throughout their length, are calculated according to the rule laid down in te specifications.

The offshoots except to groups are No. 16 B. W. G. The wire used has been of excellent quality, and is known in the trade as the Habirshaw wire. In a test of several wires for use on the *Chicago* its record was the best.

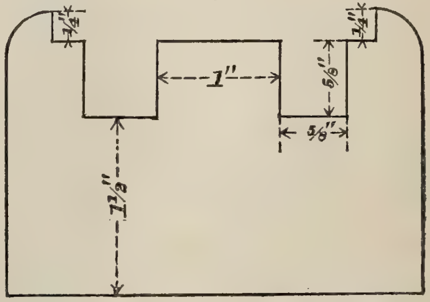
The mains and branches throughout the ship are of lead-covered wire, and are run in wooden molding of the form and dimensions as shown in Figs. 6 and 7. The molding is usually of white pine, but of polished hard wood where the wires cross such surfaces. The width of the rib separating the gutters allows of the secure fastening of the molding by means of brass screws without breaking through the sides, and thus sometimes grounding the lead covering of the wire. The thickness of the wood beneath the gutters allows the cutting away of sufficient to let in bolt-heads and the like, and still leave half an inch of the wood. The gutters allow one thirty-second of an inch all around the conductors they are to take, which avoids bruising the lead in putting the wire in. After fitting, the molding is thoroughly covered with white-lead paint. Molding should, where practicable, be coped instead of mitred.

Fig. 6.



Section molding without capping.

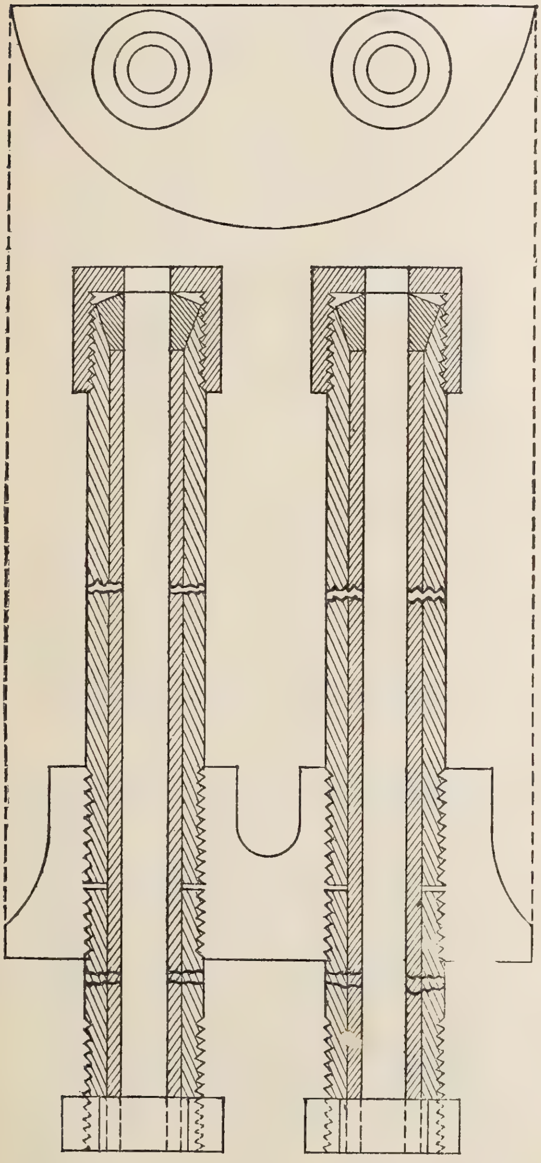
Fig. 7.



Section molding with capping.

It has been the practice to cap over only such of the molding as was deemed necessary for the protection of the lead cover from mechanical injury, or where for neatness it was thought desirable, the remainder being uncapped and having the wires held in the gutters by fibre staples. It has been found that in driving these staples injury is sometimes done to the lead covering, and if found necessary to take down the molding much of the lead cover would be destroyed. It has therefore been decided to cap all molding, as the capping offers a better protection, and with the disappearance in our work of underwriters and other inferior insulations, it is not so important that every conductor should be in sight. The present insulation is good, and being further protected from water by the lead covering, it is reasonable to presume that the continuity of the conductors will not be broken by the attacks of salt water, and in consequence there is little danger to be apprehended. Other improvements in installations, for the detection of leaks and for the measurement of resistances, give the officer in charge better opportunities than formerly to know the condition of the circuits. The objection to the use of capping is founded upon the same basis as the objection to lead-covered wire, *i. e.*, poor materials and poor workmanship.

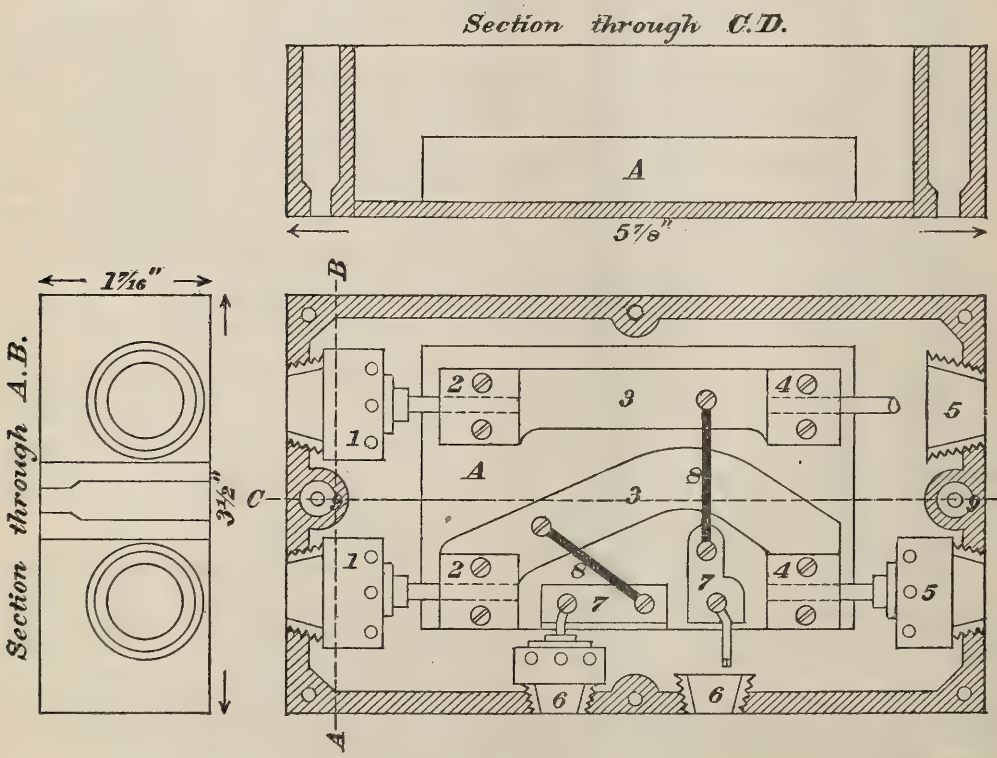
Fig. 8.



Where conductors pass through beams, bulk-heads, and the like, the openings are lined with hard rubber tubing; in passing through decks and water-tight bulk-heads, stuffing-boxes (Fig. 8) prevent the passage of water.

From a section-switch in the dynamo room to the point where a branch is to be taken off for a light, unbroken lengths of wire are run; a junction box (Fig. 9) is here introduced, the wires from the switch-board entering through the stuffing-boxes 1.1, and being firmly bound beneath the caps 2.2 by means of screws. The junction strips 3.3 have also binding clamps 4.4 at the opposite ends, from which point the mains continue on, issuing through the stuffing-boxes 5.5, and continuing unbroken as before to the next point where a branch is to be run, where another junction-box is introduced. The branch wires enter by the stuffing-boxes 6.6 and are taken to the binding posts 7.7. Between these posts and the pieces 3.3 are placed the fuses 8.8. Fuses are required to be at least 1¼ inches long and are introduced at every change in the size of a conductor. All of the metal in the box in circuit is carried upon the block "A," which may be of porcelain or other suitable incombustible material. The wells 9.9 take the screws which fasten the box in its place; these and the stuffing-boxes are put inside the junction-box merely to reduce the work of fitting the latter in place. The cover of the box is lined with rubber cloth, which, besides packing the edges of the box, packs the screw wells also. The branch wires are carried to the point at which the light is to be placed, sufficient end being left to wire the fixture, thus avoiding a splice. In order to carry two No. 16 wires into a socket it is necessary to have the entrance in the base considerably enlarged.

Fig. 9.



Junction box.

All fixtures having keyless sockets, except the special wire-guard fixtures, have switches which may be water-tight or not, depending upon the location. The one-light switches are single pole, the parts in circuit being carried upon a block of similar material to that used in the junction box; the water-tight switches being rendered so by inclosing the block carrying the switch in a water-tight bronze box, the wire entering and issuing through stuffing boxes, the switch being operated by a key through the cover of the box, the stem of the key having a stuffing box properly packed.

The water-tight receptacle for portable plugs consists of a bronze box having in the bottom a porcelain block carrying the necessary fittings for a wedge-shaped plug, the wires passing out through stuffing boxes. The cover is hinged and closed by a catch, the inside of the cover being lined with rubber cloth to pack the edges, and the portable cord being wrapped so as to pack itself as it lies in a recess between the cover and the side of the box.

The switches and receptacles not water-tight are not peculiar to the service, so need not be described, but the growing and almost general use in this country of incombustible materials only, in switches, plug receptacles, cut-outs, regulator boxes, and switch-boards, and the possibility of obtaining such articles in the market must be attributed to the requirements of the Navy Department in the installations put in under its direction.

Not only is it required that the circuits shall have a high insulation resistance, but the lead cover of the conductors, the junction, switch and receptacle boxes, and fixtures must all have half an inch of wood, at least, between them and outside metallic contact.

The fixtures have been much improved during the past year, more particularly in strength and finish. The special wire-guard fixture (Fig. 10) is the one generally employed, being adapted for fastening upon vertical surfaces. The board is made 2 inches thick to allow for cutting out at the back to let in bolt-heads and the like. The reflector is a corrugated-glass mirror; the lamp is inclosed in a steam-tight globe, the cover of which is supported by a goose-neck soldered into the switch-box. The branch wires enter the switch-box through stuffing boxes, the lead cover being stripped after it enters the packing; a special quality of fixture wire carries the current from the switch to the socket. The switch is of the same sort as that already described.

The coal-bunker fixture (Fig. 11) resembles the last, but differs in having its switch located at a convenient point outside the bunker and having a larger and heavier guard with smaller meshes. The branch wires pass directly into the socket through stuffing boxes in the cover to the steam-tight globe, the lead as in all other cases being stripped in the packing.

For lights upon the ceiling generally, the ordinary steam-tight globe fixture is employed, the branch wires passing through stuffing boxes in the cover of the globe. At the water glasses in the fire rooms and where necessary, these fixtures are protected by a light metal guard or cage. (Fig. 12.)

The state-room and office fixtures (Figs. 13 and 14) are supplied with a cord of sufficient length to permit their use in any part of the room.

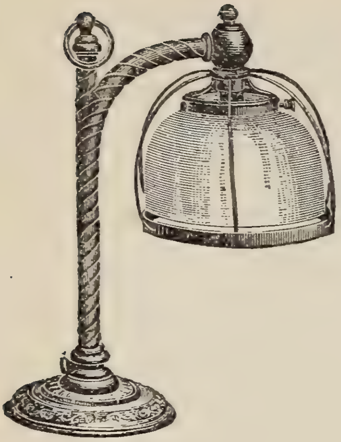


FIG. 13.

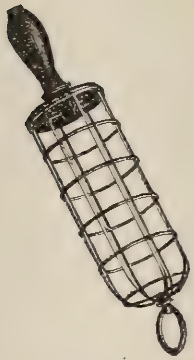


FIG. 15.

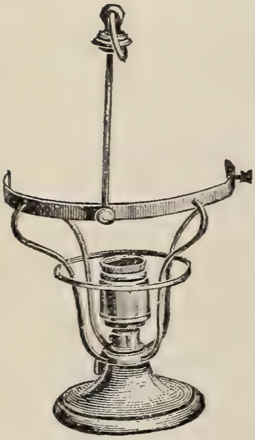


FIG. 14.

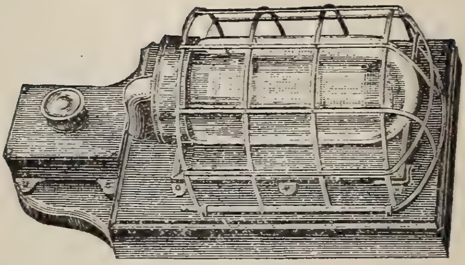


FIG. 10.

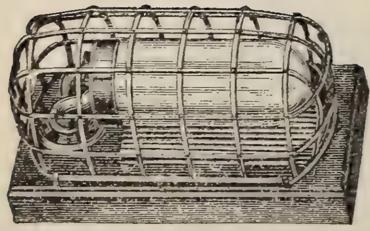


FIG. 11.

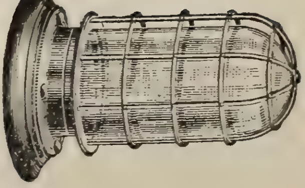


FIG. 12.

The portables supplied for use in holds, boilers, double bottoms, and similar places (Fig. 15) are provided with enough cord for the purpose, and are light and not easily injured.

Cabin and ward-room countries are fitted with electroliers or ceiling fixtures, the kind depending somewhat upon the height of the ceiling.

The running lanterns contain two 16 candle-power lamps supported from the top of the lantern, which is made thoroughly water-tight, the flexible cords passing out through stuffing boxes, each plug going to its own receptacle. The lens heretofore employed is still used, the lamps being placed as advantageously as practicable and having a reflector behind them.

Other special fixtures are sometimes used as well as the ordinary bracket, pendant, etc., such as are installed on shore.

No satisfactory finish for fixtures has yet been obtained, everything yielding to the attacks of salt air and salt water. Nickel has been tried several times, but in each instance with very unsatisfactory results. At present bronze is used without any coloring, except in certain of the fixtures in cabins and ward-rooms, which are treated with acid.

Trouble has been experienced with the insulating parts of sockets and the rachet wheel of the one-light switches; these parts were made of "fibre" and also of other materials of unknown composition and brief life-time, and it has been found necessary to reject all of them as they take up moisture, and upon drying become distorted or disintegrate. Lava will probably be used in their stead.

All lamps are of 80 volts and require 4 watts to the candle-power. They are of 10, 16, 32, or 50 candle-power each. Having adopted lamps of these dimensions as standard and having in view the adoption of a standard socket and standard fixtures, ships abroad will be enabled to transfer stores to each other, which has not heretofore been practicable.

The ships as now installed are liberally fitted out, and with intelligent supervision and attendance, and the absolute prohibition of meddling with any part of the circuits, lamps, etc., by those not authorized, there need be little trouble anticipated. The tendency of thoughtless persons is to waste in using light when not required. A lamp used unnecessarily is not only consuming its guaranteed life, but fuel is wasted. The cost of lamps is an important item, and while this method of illumination is expected to promote health and comfort among the ship's company, extravagance is apt to occur and should be guarded against. An old lamp having lost a part of its power may still be of service in storerooms and other places where such a light would suffice. Care should be taken to clean daily the lamps, globes, and shades, if the best effect would be produced for the power expended.

Some trouble and inconvenience would be saved if the circuit be broken upon putting in or taking out of circuit a lamp or a portable plug. Neglect of this often causes the melting of the fuse with the delay in consequence necessary for its renewal.

Junction and switch boxes not properly closed are often found to be the cause of a "bad" ground. Careful, steady men should be selected to operate the plant. Attention to seeming trifles will keep everything in order and diminish accidents, which in most cases are caused simply by neglect. Attendants who have had little experience are usually either afraid of the machine or they feel that they have acquired about all that is worth knowing; of the two, the uncertain man is to be preferred, as he will in time acquire confidence, but the latter will often cause trouble by meddlesome acts the consequences of which he is not wise enough to foresee. A favorite place for the operations of these is the commutator, which, if they are not checked, would soon be worn away by frequent dressing down with the file. This should be prohibited by the officer in charge of the machines, who should allow neither file nor sandpaper to touch the commutators except by his direction. The expenditure in brushes should be watched, as these are likely to be worn away more under the file than on the machines. With everything in working order and an intelligent set of attendants it should not require more than fifteen minutes per day of the time of the officer having charge of the installation.

2.

DEVELOPMENT OF THE INSULATION OF ELECTRIC CONDUCTORS FOR NAVAL USE.*

By Lieut. R. C. Smith, U. S. Navy.

The secret of all success in electric lighting, and especially aboard ship, is a good, durable, and well-protected insulation. This is the initial and absolute essential; other points are largely matters of detail. In the early days this fact, if recognized, was not fairly considered. To-day, and thanks in a large measure to the Office of the Naval Inspector of Electric Lighting, established in 1887, not only the installations in the cruisers now building, but from competition amongst manufacturers, drawing their inspiration from the requirements of that office, commercial plants as well, give evidence of increased excellence in this regard.

It does not seem to be difficult to manufacture an insulation that will answer all requirements when new. The great trouble has been to obtain durability when subject to the varying conditions of heat and cold, dryness and moisture, and the rough treatment incidental to use aboard ship. Vast quantities of materials have been brought into requisition, such as resins, which are usually too brittle, or when mixed with tar too easily softened by heat, allowing the conductor to sink through; asphaltum and bituminous compounds, which have been favorably mentioned; tar and pitch, not regarded as trustworthy when used with rubber or gutta-percha, the latter suffering injury from the action of the solvent oils; paraffin, which shrinks on cooling, and tapes soaked in the latter, which are rotted by the free acid; asbestos, which resists heat and the action of acids, but absorbs moisture; ozokerite, a crude native paraffin, originally like petroleum, but from which the more volatile components have escaped, found in Galicia, lately in Utah, applied in various ways to rubber, supposed to shorten the life of the latter; cotton, silk, flax, and jute, with or without shellac or paraffin, which do not withstand changes of temperature or moisture; gutta-percha, better than most of the above, but must be kept under water or at a uniform temperature, hence unsuited to ship's use; and lastly, india-rubber, well-nigh universally recognized as the most desirable material, but on account of its comparatively high cost not used to a considerable extent in its pure state, but more or less adulterated with many of the above-mentioned substances. In this brief list no mention has been made of the numerous patented compounds, which possess greater or less excellence according to the care and cost of their manufacture and the use for which they are designed; but it is safe to say that not one of them equals in insulating properties and durability under changing conditions pure india-rubber, but in the struggle to obtain a cheaper commercial article approximates to it in excellence more or less in the ratio of its cost.

---

* Most of the information contained in this article has been gathered from the files and publications in the Office of the Naval Inspector of Electric Lighting.

The qualities recommending pure rubber are its high insulation, its durability, flexibility, elasticity, its power of withstanding changes of temperature and moisture, and its immunity from the harmful action of most acids. There are of course cases in which it is not necessary to use pure rubber for the whole thickness of the insulation. For large conductors, such as are used for electric lighting, it is sufficient to have a layer of pure rubber to begin with, and vulcanized-rubber compounds and tapes outside. In all cases it is necessary to prevent access to the copper of the sulphur of vulcanization, as the former would be thereby soon attacked and corroded. Likewise the pure rubber must be protected from any possible heating of the conductor when accidentally traversed by strong currents. These objects are attained in the best wire of to-day as follows. The copper strands are covered with a heavy, smooth, and uniform coat of tin. The latter metal resists most of the chemical actions that would injure the copper. The conductor, of a single or several twisted strands, is then wrapped with a thoroughly dried cotton parceling, or is braided with cotton, and is soaked in a pure rubber solution. After that comes a ribbon or sheet of pure rubber, technically called brown rubber, then a layer of rubber containing no sulphur, usually mixed with zinc oxide, and called the white rubber or separator, then a layer of vulcanized rubber, called black rubber, or a layer of okonite, and lastly a cotton parceling, or preferably a braiding, soaked in ozokerite or some insulating compound. A disadvantage in having cotton next the wire is that it collects moisture. This may be prevented by having it thoroughly dry when put on and applying the pure rubber at once in a dry atmosphere. An incidental advantage is that it keeps the surface of the wire clean and bright. The real reason for its use, however, is that it keeps the pure rubber from softening when the conductor is overheated. Para rubber is the best and purest form in use and is stipulated in the latest Navy contracts. The outer layer is vulcanized to render it more durable, and the white rubber separator prevents the sulphur from penetrating. A lead covering is now generally used in ship-lighting. It must be pure and soft to stand bending, and thick enough to resist abrasion.

Its object is to prevent access of salt water to the conductor, and to permit the whole system to be made water-tight. An incidental advantage is that it prevents to a great extent the drying and cracking of the insulation. Tin is sometimes alloyed with the lead in underground conductors, and is said to render it less liable to oxidation and pitting. A covering of jute gives it additional protection.

It is not to be supposed that such insulation as this was manufactured a few years back. It will be interesting to follow its development as shown in plants so far installed in ships of the Navy. The *Trenton* was the first man-of-war lighted by electricity, and was installed by the Edison Company in the summer of 1883. The specifications required that the conductors should be of the most improved pattern used by the Edison Company for Isolated Lighting. The present inspector of electric lighting supervised the installation in a general way and served as executive officer of the ship during the ensuing cruise. The company, however, was primarily responsible for the material, having ample latitude under the contract. It is safe to say that they supplied the best insulation at that time to be had in this country, though fears were entertained of its ultimate adaptability to the requirements of ship-board. (See article on Electric Lighting in No. VI.) The conducting mains were of a single strand of copper in two sizes, Nos. 12 and 14 B. W. G. (Plate, *a*, *b*). The larger wire was covered with three braidings of cotton, the inner one soaked in bituminous compound and the outer one painted. The smaller wire was wrapped with cotton thread, soaked in a compound, then braided with cotton and painted. Neither of these insulations proved efficient. The first answered fairly well, but principally owing to the protection afforded by well painted wooden moldings inclosing the wire. The second frequently gave out, softening and allowing salt-water to reach the wire, with results described in No. VI. The branch wires for single lamps were of two sorts, both No. 18 B. W. G., one tinned and rubber coated, the other similar to the No. 14 above (Plate, *c*, *d*). The rubber was of poor quality, broke off and did not stand heat. The coating of tin, however, prevented the access of salt-water and consequent corrosion. On that account it was recommended in the future to tin thoroughly all wires for ship-lighting. The other branch wire proved worthless and had to be replaced during the cruise. The vicious effects of salt-water seemed so apparent that a lead covering for all wires was recommended. Thus it is seen that this plant, while in the main successful, afforded valuable lessons for future guidance.

It will be proper here, in point of time, to mention two installations, both by the Edison Company, which, while intended to be of the best, were not directed by the Bureau of Navigation, and were not on the lines of the experience gained in the *Trenton*. The first was the *Dolphin*, in the summer of 1884. The building contract required her to be lighted by electricity, and the contractor was at liberty to select any system. The conductors employed were of copper, tinned, insulated with rubber, and parceled with rubber tape. In the smallest size a painted cotton covering took the place of the rubber tape. Moldings were not generally used, but in some places a light batten was employed for appearance or for protection from salt-water. This type of conductor has proven fairly satisfactory. In some cases water has reached the wire with the usual corrosive effect, though the faults were stated to be due to improper leads and carelessness in wiring rather than to the character of the insulation. It was recommended to paint the parceling.

The other installation referred to was that of the *New Hampshire*, in the autumn of the same year. Her mains were of No. 16 double conductor wire. Each strand was first parceled with cotton and served with thread, and the whole soaked in melted paraffin. The two were then wrapped together with rubber tape and thread and again paraffined. The idea of this poor insulation of the mains from each other was that in case of a fault or short circuit, before the current could do much damage, the insulation would be heated and perforated, the conductors would come together, act as a fuse, and the circuit would be broken. This system was not successful in practice. Safer and more economical means can be devised to accomplish the same end. For the branch leads, two sizes of wire, Nos. 17 and 18 B. W. G., both tinned, were employed. The former was rubber insulated and parceled with tape, and proved the most satisfactory of the installation. The other was insulated with gutta percha, which, as has been seen, does not stand change of temperature, is brittle when cold, cracking and breaking, and soft when hot, allowing the wire to sink through. No moldings were used; salt-water penetrated the insulation and corroded the wire. The double conductor mains were shortly replaced by torpedo wire. In the spring of 1888 the ship was entirely re-wired with okonite wire led in wooden moldings. It is reported to give satisfaction.

In the summer of 1884 specifications were got out for the *Atlanta*, *Boston*, and *Omaha*. They were identical in requiring the conductors to be of copper wire, tinned, insulated, and laid in pure lead tubing. The *Omaha*, installed by the Consolidated (Sawyer-Man) Company, was the first completed, in the spring of 1885. Two sizes of conductors were used, Nos. 6 and 16 B. W. G., consisting of a single strand of copper, tinned, insulated with two layers of cotton braiding soaked in paraffin, and lead-covered (Plate, *e*, *f*). They were secured by iron staples and were generally without the protection of molding. The first reports on this wire were favorable. In the latter part of 1887 leaks were first noticed, the lead having been found cracked and the wire corroded. In the beginning of 1888 the ship was recommissioned for another cruise and large quantities of new material sent out to replace the old. The new wire was rubber insulated, lead covered, and similar to the best samples of the time, to be described later. In regard to the old wire then in the ship, that on the spar-deck and engine-room circuits was described by the officer in charge of the plant as completely useless. The lead covering had been cut through by the staples, the cotton insulation rotted by salt-water, and the wire grounded. It was considered that a lead covering, on account of the facility it afforded for grounds, was not desirable except with perfect insulation, and iron staples, it was thought, should never be used. In the later installations the practice has been to use a flat fibre staple to secure the lead-covered wire in the moldings. The material is tough and elastic and is not affected by salt-water. Specially devised instruments are employed to puncture holes for them in the wood and to set them home; they do not stand driving with a hammer. The driving tool should be constructed in such manner as to prevent setting home too hard and thereby cutting the lead.

Next we come to the *Atlanta,* installed by the United States Company (Weston system), and finished in the autumn of 1886. Two sizes of wire were used, Nos. 10 and 18 A. W. G., each a single strand, tinned, wrapped with thread, covered with a preparation of rubber, a paraffined braiding, and a lead coating (Plate, *g*, *h*). This wire answered for awhile. The first report of broken lead, entrance of salt-water, and corrosion was in the second quarter of 1888. The trouble occurred in the after orlop, though other portions must have been more exposed. It is an instance of how salt-water finds its way everywhere. Portions of this wire subjected to continuous heat over the boilers gave evidence of a thorough baking and disintegration of the insulating materials. The process of vulcanization is apt to go on under these circumstances till all the rubber is a solid mass. The separator and pure rubber must be depended on to stop the injurious action. In 1887 samples of okonite wire, with and without lead cover, were received for trial (Plate, *i*, *k*). These samples were of the same size as the original conductors, had a layer of okonite next the tinned wire and a braiding soaked in an insulating compound. The lead-covered sample was reported to be better than the original wire.

The *Boston* was installed by the Brush Company, and finished in the spring of 1887. The wire supplied was like the *Atlanta's* in every respect. In the third quarter of 1887 it was reported that salt-water got to the wires where passing through the steel decks. Bad insulation was assigned as the cause. During the installation of these two ships they were inspected from time to time by the present Naval Inspector, though the specifications and contracts were made before the establishment of his office. Their plants were certainly superior to any previously installed, and, in spite of the faults enumerated, fairly efficient.

The next wiring to be considered is that of the *Chicago*, installed by the Edison Company, contracted for in December, 1886, and finished in the spring of 1888. The specifications required that the conducting wires should be tinned, covered with the best rubber insulation, and inclosed in pure lead tubing. A sample of not less than 500 feet in length should, after at least 24 hours' immersion in sea water, possess an insulation resistance of not less than 1,000 megohms per nautical mile. The conductors were of various sizes from No. 6 to No. 16, and of a single strand of copper, tinned, insulated with the white and black rubber and rubber tape, and inclosed in a lead tubing (Plate, *l*, *m*, *n*). It was found on wiring that the larger sizes were not flexible enough, and the lead cover, from insufficient thickness, sometimes broke in bending. These two faults have been remedied in later specifications, by requiring all large conductors to be stranded, and the lead cover to be at least 0.04 inch in thickness. Another advantage in stranded conductors, in addition to greater flexibility, is that all the wires are not apt to be broken together, the breakage of one or two not being fatal. But if a single conductor parts, the circuit is broken and the fault is harder to repair, if indeed it is not entirely concealed by the insulation. Lighting companies were, on account of the increased cost, loath at first to make this change, but the advisability has now been generally recognized. The *Chicago's* plant has been in frequent operation for considerable periods, and has proven satisfactory. No opportunity has been afforded of testing the insulation in actual service at sea, but it is thought that it will fulfill the requirements. This was the first instance of stipulating a definite insulation resistance in the specifications. It is now a feature of all contracts.

The re-wiring of the *Trenton*, likewise by the Edison Company, dates from this time. Contracted for a few months later than the *Chicago*, she was finished nearly a year earlier. The specifications were in the main similar, but there was the additional requirement that no conductor should contain a wire of greater diameter than a No. 16 B. W. G., but that the necessary area should be made up of smaller wires, in order to produce flexibility. The *Trenton* being a wooden ship, the Bureau was of the opinion that with a good rubber insulation a lead tubing would not be necessary. This requirement was therefore omitted. The wire was manufactured by the India Rubber and Gutta Percha Insulating Company of New York, the same firm that had supplied the Edison Company with wire for the *Chicago*, and that has since furnished all the wire installed in ships of the Navy. They are fully equipped to turn out any amount of the best insulated wire that may be required. The mains for the *Trenton* were of two sizes, using seven strands each of No. 16 and No. 18 wire respectively, or, as they are denominated technically, $\frac{7}{16}$ and $\frac{7}{18}$ (seven-sixteens, seven-eighteens). The branches were a single strand, No. 16. The leads from the dynamo to the switch-board had a core of seven $\frac{7}{16}$ cables twisted together, making in all forty-nine strands. These conductors were all tinned, parceled with cotton soaked in a rubber solution, and insulated with layers of brown, white, and black rubber successively, and lastly a parceling of rubber tape (Plate, *o*, *p*, *q*). The reports received from this ship were in the main satisfactory.

Her unfortunate loss at Samoa has made it impossible to know how the insulation would have stood the further test of time.

The *Yorktown* is the last ship installed, and involves all the improvements suggested by previous experience (Plate, *r*, *s*, *t*). The contract was sublet by the builders to the Edison Company on specifications drawn by the naval inspector. The part relating to the character of the insulation is quoted in full.

> All conductors, except fixture and portable wires, shall have—
> (*a*) A layer of fine braided cotton.
> (*b*) A layer of rubber containing no sulphur.
> (*c*) A layer of vulcanized rubber or okonite.
> (*d*) A parceling of rubber tape.
> (*e*) A water-proof covering of pure lead not less than four-hundredths of an inch thick. The insulation, exclusive of cotton and lead, shall not be less than three thirty-seconds of an inch thick. It shall, after twenty-four hours immersion in sea water, have a resistance of not less than 1,000 megohms per nautical mile. * * *
>
> A sample of 500 feet of the regular pattern of conductors to be forwarded to a place designated for testing.
>
> The physical characteristics of the insulation shall not change when the conductor complete is raised to the temperature of boiling water nor upon cooling.
>
> * * * * * * *
>
> *Insulation.*—When complete, with all connections made ready for the use of each and every lamp, the insulation of the entire system of conductors, including the circuits of the dynamo, shall not be less than 1,000 ohms of resistance to every volt of electro-motive force of the dynamos. The outer coating of all conductors, all fixtures, junction-boxes, switches, receptacles for portables, and all other exterior parts of the system, shall be insulated from the ship. All junction-boxes, switches (unless otherwise designated), conductors, joints of conductors, and entrances to fixtures shall be water-tight. The interior insulating block of junction-boxes and water-tight switches and the bases of other switches and receptacles, also the switch-board, shall be of porcelain, slate, or marble.

In making this wire the manufacturers applied first a layer of pure Pará rubber over the braided cotton, which was beyond the requirements of the contract, and then the other layers as above enumerated. The conductors were accepted after a number of tests which were deemed satisfactory. It is too early yet to make predictions, but in two or three months' use there is absolutely no fault to find with the character of the insulation.

The wire supplied the *Pensacola*, the *Charleston*, and the *Baltimore* is similar to that of the *Yorktown*. The dynamo leads are now made in a single cable of the requisite number of strands, instead of a number of seven-stranded cables laid up together, as furnished the *Trenton*. On account of the difficulty of braiding over a number of loose strands, a parceling of cotton is used next the wire. This answers the requirements equally well. An improvement has been made in the matter of the outer parceling, which in some cases worked loose in bending, by substituting for it a close braiding of cotton and soaking in ozokerite.

The flexible conductors for portable lights are of an improved form, suggested by gradual experience, and will be briefly mentioned. The double-conductor form seems to be the most desirable when sufficiently flexible, as it is less likely to kink than the separately insulated and twisted strands. It was made at first with an inner stranded conductor, and the strands of the outer one disposed at intervals about it. An extra strand was put in the outer conductor to provide increased cross-section, and compensate for the extra resistance due to the greater length of the outer spirals. When these were tried in the *Yorktown* it was found that the outer strands, receiving no mutual support, were apt to be broken by continual bending at the point of entering the fixture or plug. A new form, now on trial, contains two stranded conductors insulated and laid side by side, with jute fillers to give a rounded cross-section, and a double hemp braiding soaked in ozokerite laid on over all. The resulting wire is flexible and bids fair to answer well. For use in cabins and officers' quarters a braiding of floss silk has been employed instead of the hemp. Lately, twilled silk has been substituted, making a smoother and more durable finish. For fixtures that will not admit the regular branch leads, a small stranded conductor is used. The core consists of three No. 25 wires, tinned, insulated with white rubber, vulcanized rubber, and a fine cotton braiding soaked in ozokerite.

While not in this immediate connection, it will not be amiss to mention that the Interior Department building in Washington has been wired during the current year with tinned, rubber insulated conductors of the same type as those now used for ships of the Navy. At the request of the Secretary of the Interior, the specifications were prepared and the work supervised by the Naval Inspector. The insulation resistance of the system is remarkably high. About eleven hundred lights were installed, half on gas fixtures. Each lamp attachment was insulated from the chandelier, and the latter themselves insulated with hard-rubber joints. After frequent testing, the insulation resistance of the system has never fallen below 2 megohms, a result about two hundred times greater than required by Professor Jamieson's rule published in the recent edition of the Pocket-Book which is, in effect, $R = \frac{100,000\ E}{N}$ ohms, or for 1,000 lamps at 100 volts, 10,000 ohms. Calculating the insulation resistance of the *Yorktown's* system by this rule, the result is $R = \frac{100,000 \times 80}{240} = 33,333$ ohms. The specifications require $80 \times 1,000 = 80,000$ ohms. It is expected that this requirement will eventually be exceeded.

RESULTS OF SOME INSULATION TESTS OF ELECTRIC LIGHT CONDUCTORS.

Three samples of wire for the *Yorktown* were tested by the writer, two at the Naval Academy in September, 1888, and one at the University of Pennsylvania, by the courtesy of Professor Barker, in October of the same year. The Naval Academy samples were supplied by the contractor in accordance with the specifications. They were each of about 500 feet of No. 17 B. W. G. wire, tinned and insulated, one with and one without a lead cover. The Philadelphia sample was 450 feet in length of $\frac{7}{15}$ tinned, insulated, and lead-covered wire, and was taken directly from the ship when supplied for installing. It is now a part of the forecastle and spar-deck circuit.

On account of the short lengths and relatively high insulation, it was found necessary to use the loss-of-charge instead of the direct method. The latter is the simpler and consists in sending the current of a powerful battery through the insulation, and measuring its strength with a sensitive galvanometer. The resistance in circuit is found from the electromotive force of the cells and the strength of the current. The cable is immersed in a tank of water leaving the ends clear. One pole of the battery is in contact with one or both ends of the conductor, and the other pole is placed in the water. The current thus passes through the insulation. The longer the cable, the greater the leakage, and the more sensible its effect on the galvanometer. When the lengths are small and the insulation high, the leakage is so slight as to be with difficulty measured. Recourse is then had to the loss-of-charge method. Here account is taken of the loss which a definite charge sustains by leakage through the insulation in a given time. Without going into details, the charges are compared before and after the time interval, and the insulation resistance calculated by a known formula. The first method is generally preferable, as the galvanometer shows continuously the strength of the current, and any change of resistance during electrification is at once perceived. In the second method, we find only the average resistance during the interval, and nothing is known as to any change in the interval. Nevertheless, by using different intervals, and forming a curve of the corresponding average resistances, we may eventually know the actual resistance at the end of any time. The work is more tedious, but if carefully done there is no reason why the results should not be equally reliable.

On first closing a circuit through the insulation of a conductor there is in the direct method a marked deflection of the needle. This slowly decreases, until finally the needle settles down to a permanent position. This would indicate a low resistance at the start and a gradual increase as the process of electrification goes on. Much of this effect is no doubt due to the condenser action of the cable and the flow of the electrostatic charge. In common practice the insulation resistance is measured after an electrification of one minute. In the loss-of-charge method, to attain the same result, a longer time interval must be allowed, as the resistance found is the mean in the interval. Assuming the curve to be nearly straight at this portion, the mean of two minutes may be taken without great error as the result desired. As the curve is slightly convex from above, any small error will be in favor of the manufacturer.

A very much more likely source of discrepancy in apparently similar observations by whatever method is a failure to make due allowance for a variation of temperature. This point will bear looking at. Denoting by A and B the Naval Academy samples, the former uncovered, the latter lead covered; and by C the Philadelphia sample, lead covered, their measurements were as follows:

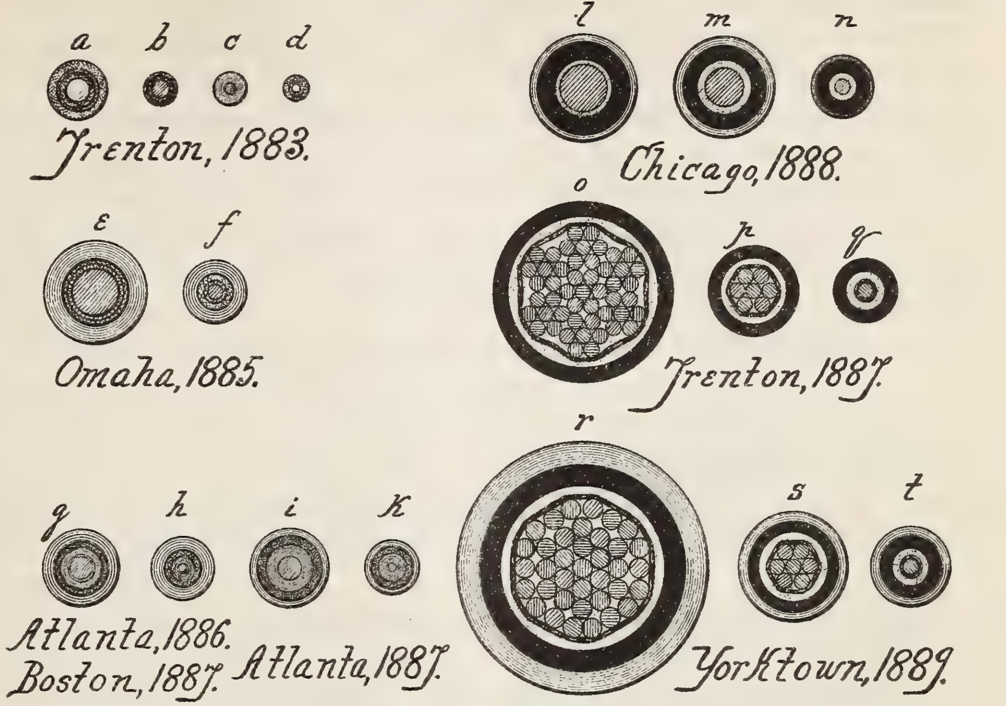
	A.	B.	C.
	Inch.	*Inch.*	*Inch.*
Total diameter over insulation	0.250	0.250	0.383
Diameter over conductor	0.057	0.057	0.202

The insulation resistances per nautical mile after one minute of electrification and immersion for various lengths of time in brine of the saturation of sea water were as follows:

	A.		B.		C.	
	Megohms.	Temp.	Megohms.	Temp.	Megohms.	Temp.
On immersion	....	....	....	....	1,480	59
After one day	2,354	74	2,185	72	1,007	63
After two days	2,221	74	2,678	72	....	....
After three days	2,534	73	2,809	68	1,083	62
After four days	2,890	71	2,863	68	....	....
After five days	2,454	72	3,249	68	817	65
On removal	....	....	....	....	1,003	....

From a comparison of these figures and the fact that cables B and C were lead covered, preventing access of water to the insulation, it is thought that the time of immersion had no appreciable effect in changing the resistance. A consideration of the temperature variation may explain the difference. Figures 1, 2, and 3. show the temperature-resistance curves for A, B, and C, respectively. In case of several observations at the same temperature, the means have been taken. There is clearly a falling off in insulation resistance as the temperature rises. The lower insulation resistance of cable C is partially accounted for by its larger size and the fact that the thickness of its insulation was less than in the smaller samples. With uniform layers of perfectly similar insulation the resistance varies as the logarithm of the ratio of the exterior and interior diameters. This would make the insulation of A and B about 2.3 times greater than that of C at like temperatures.

In further illustration of the variation of insulation resistance with temperature, Figs. 4 and 5 are added. The data in Fig. 4 were taken from a number of tests made at the Naval Academy during the past winter by Lieutenant Howard. The conductor was of $\frac{19}{17}$ B. W. G. wire,



Cross Sections of Electric Light Conductors, Natural Size.

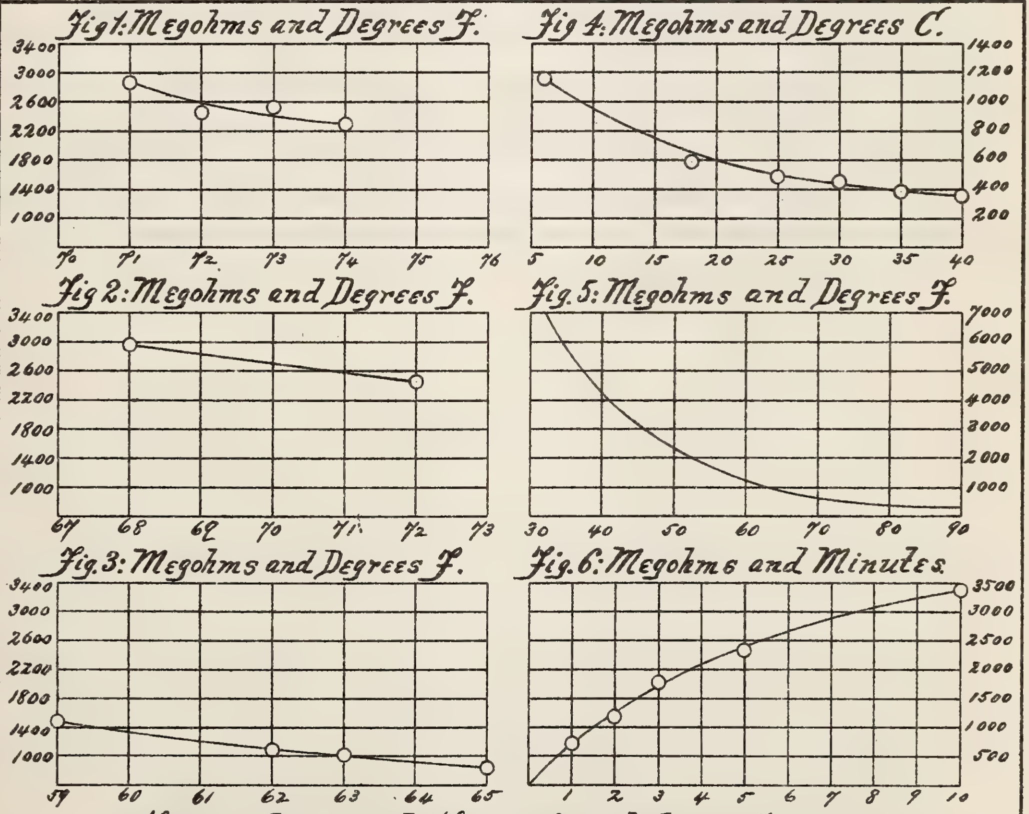


Fig 1: Megohms and Degrees F.

Fig 4: Megohms and Degrees C.

Fig 2: Megohms and Degrees F.

Fig. 5: Megohms and Degrees F.

Fig. 3: Megohms and Degrees F.

Fig. 6: Megohms and Minutes.

Temperature and Time Insulation Curves.

similar to that used in the Interior Department installation. Fig. 5 is taken from an article by Mr. Lant Carpenter on "Ocean Temperatures in Relation to Submarine Cables," in the Journal of the Society of Telegraph Engineers and Electricians for November, 1888, and shows the variation in insulation resistance of gutta-percha-covered cable for a range of temperature from 30° to 90° F. It seems, therefore, that india-rubber and gutta-percha are alike affected by variation of temperature. This fact is important, when it is considered that conductors aboard ship are exposed to temperatures varying over the whole range from the freezing point or lower to the high temperature maintained near the boilers. In order to meet these extremes the highest possible insulation at ordinary temperatures becomes a matter of necessity. Insulation resistances are usually estimated at 75° F., which is taken as a standard. One other curve (Fig. 6) is added to illustrate the increase of resistance with time of electrification. The tests were among those made by Lieutenant Howard, previously referred to. The temperature was about 5° C.

The main points to be considered in effective insulation of ship-lighting plants have now been touched on. Nothing has been said in regard to the fixtures themselves. Here also great care is necessay, not only with respect to insulation and water-tightness, but with regard to the material, appearance, and light-giving efficiency. After every precaution has been adopted that previous experience suggests, much depends on the care bestowed on the plant by those responsible for its satisfactory performance. In the present state of electrical science it is not claimed that anything is settled once for all. It is believed, however, that in the ships of the Navy now wiring, a point of excellence will be attained not hitherto excelled and infrequently equaled.

3.

USES OF ELECTRICITY IN THE NAVY.

By Ensign GILBERT WILKES, U. S. Navy.

The applications of electricity in the Navy and their development up to June, 1888, have been so thoroughly treated in previous volumes of the General Information series, that nothing remains but to supplement the articles in Nos. VI and VII of these publications by pointing out the developments of the past year, and endeavoring to determine how we shall best serve our needs in the near future.

The progress of the introduction of applications of electricity, daily increasing, is such a true growth, though rapid, and generally along well-defined lines, that in every part of this article reference will be made to the above-mentioned publications. In dealing with the present year, and the preparatory work now being done for the months to come, a new division of the subject becomes necessary—the uses of electricity at naval shore stations, where the requirements are not simply those of central station lighting on shore, but are modified to meet the peculiar demands of the service in ways which are outlined later. For convenience, therefore, let us consider the subject under two general heads: The uses of electricity—I. On shipboard; II. At naval shore stations.

USES OF ELECTRICITY ON BOARD MEN-OF-WAR.

The general considerations as to the location of the plant are discussed in the articles above referred to. In addition, it may be remarked that the dynamo room should be as far removed as possible from the compasses (forward, if the standard is to be aft); it should be as near the fire-room as possible, to reduce steam piping and loss due to condensation to a minimum; the balancing of these requirements with those already treated and the location of space for other purposes must be a matter for compromise.

The equipment of the new vessels and some of the old ones with electric-lighting plants, the excellent requirements for the work insisted upon by the naval inspector of electric lighting, and the increased liberality of Congress in dealing with appropriations for the building up of a new navy, have made the study of marine dynamos and their necessary driving power of sufficient commercial importance to attract the attention of American manufacturers to this separate field. In consequence, several forms of low-speed machines have been designed and built; special high-speed engines have been placed upon the market, and complete plants of engines and direct-driven dynamos of high efficiency have been completed for four vessels—the *Yorktown*, *Baltimore*, *Charleston*, and *Pensacola*. In all, except the old ship last named, the plant consists of duplicate units of engine and dynamo.

The standard electro-motive force, or pressure, in use on board our men-of-war is 80 volts. The new machines are all compound wound multipolar dynamos of the style shown in Fig. 1. All of the iron parts of the magnetic circuit are wrought, with the exception of the cast-iron keeper, which also serves to support the magnets. There are eight poles, the four outside ones being north, the four inside the armature being south and 45 degrees distant from the former. With this construction an overhanging armature becomes a necessity, but it is well balanced and secured to the shaft by means of an eight-armed bronze spider. The armature core is built up of thin sheet-iron laminated rings, insulated with prepared paper. The end rings, however, are solid brass and through bolted to the spider, whose alternate arms are insulated from the armature core, in order to prevent the currents which would be set up in the arms, owing to the fact that they are cutting fields of opposite directions.

This type of machine was especially designed by the Edison Manufacturing Company in order to meet the requirements for the lighting of the new ships. As originally designed the machine was intended to have four pairs of brushes, and several other points have been altered in the original plan of construction.

The duty of testing these machines, for which the writer was detailed, and the development of the first commercially successful and efficient slow-speed dynamos in this country have been full of interest. Both the naval inspector of electric lighting and the writer objected on both theoretical and practical grounds to the large number of brushes, but the company preferred finishing one machine on this plan in order to demonstrate which would give the better results. The tests resulted very favorably for the plan of having only two brushes, and demonstrated beyond question their superiority both as regards non-sparking and attention necessary. The armature core forms a thin, hollow cylinder, and its distorting effect upon the field is very slight, the change of position of brushes between no load and full load being less than 10 degrees, while for variations of one-half load no change is necessary if the brushes are first carefully set.

The important bearing of these facts upon the manipulation of searchlights where the load is constantly changing is evident. A slight modification that is to be made in the dynamo in the future will, it is thought, allow the load to be changed from zero to full load without any shifting of the brushes.

Fig. 1 is a view of one of the *Yorktown* dynamos (100 ampères) driven by an Armington & Sims engine. Figs. 2 and 3 show elevation of one of the dynamos of the *Charleston* (200 ampères), driven by a vertical compound engine, and plan of bed-plate for the same. All of the new machines are driven at a speed of 400 revolutions per minute.

Table of data of engines and dynamos of U. S. S. Baltimore.

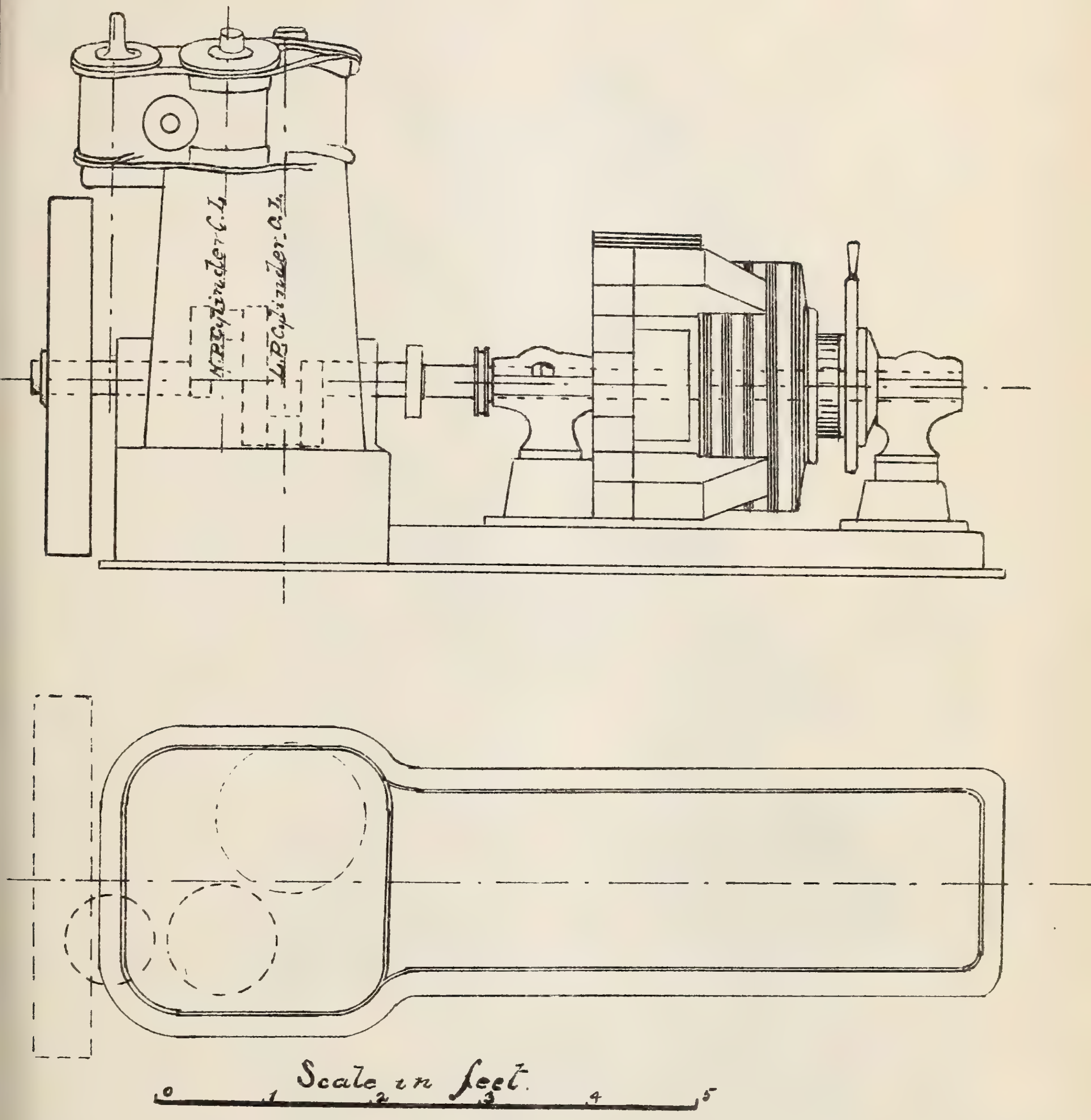
Weight of dynamo without armature	pounds	2,557
Weight of armature	do	813
Weight of engine	do	2,230
Weight of bed-plate	do	1,143
Weight of dynamo part of bed-plate	do	461
Weight of engine part of bed-plate	do	682
Weight of dynamo complete (without bed-plate)	do	3,370
Weight of dynamo complete (including dynamo part of bed-plate)	do	3,831
Watts generated at full load		16,000
Watts per pound of dynamo		4.75
Watts per pound of dynamo, engine, and bed-plate		2.37
Floor space occupied by engine and dynamo	square feet	24.7
Power of plant in 16 candle-power lamps		250
Floor space per 16 candle-power lamps	square inches	11½
Weight of plant complete per 16 candle-power lamp	pounds	27

A comparison of the latter part of this table with that given on page 215 of General Information Series, Vol. VII, will show the comparative excellence of these new plants. A vertical, double-acting engine is now on the market, which runs at a speed of 750 revolutions. Using such an engine and designing the machines for this speed, it is evident that a very large reduction could be made in the weight and floor space per 16 candle-power lamp. However, 400 revolutions seem more fitted for constant work on board ship, though the dynamos for some of the smaller vessels may be driven at the higher speed mentioned.

Electrical data of the plant of the Baltimore.

Electro-motive force	volts	80
Ampères		200
Resistance of armature at 60° F		.0177
Resistance of series field at 60° F		.005
Resistance of shunt field at 60° F		5.8
Turns in series field		18
Turns in shunt field		1,480
Ampère turns in series field		3,600
Ampère turns in shunt field		10,370

The series field is wound with two nineteen, strand cables (each strand being 95 mils in diameter) in multiple, the shunt field with wire having a diameter of 128.5 mils. The armature contains one hundred and twenty sections, having eight turns to each section. Its winding consists of six wires of 57.1 mils diameter wound in multiple in order to give a



Figures 2 and 3,
Engine and Dynamo of U.S.S. Charleston

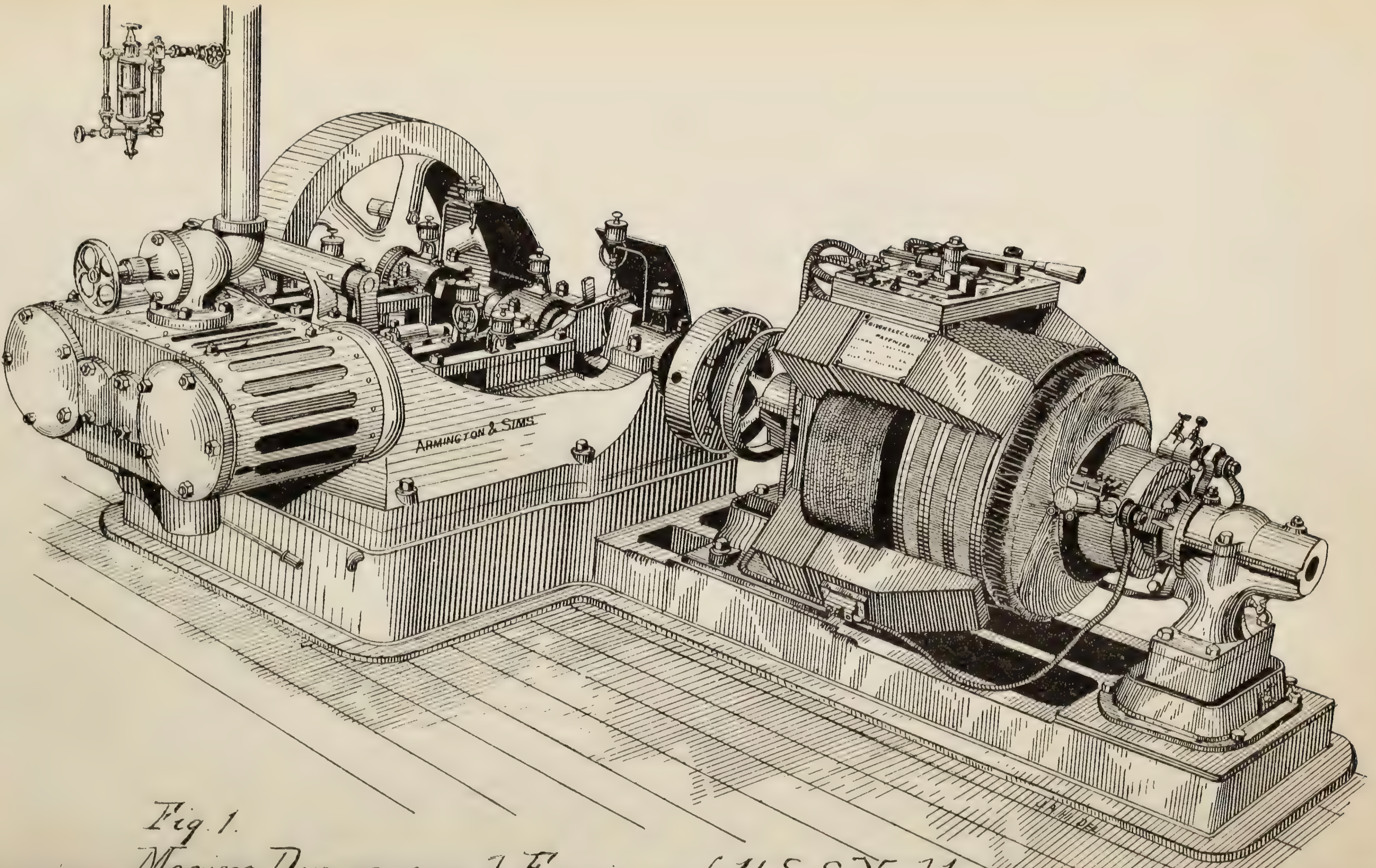


Fig. 1.
Marine Dynamo and Engine of U.S.S. Yorktown.

smooth finish. The commutator has one hundred and twenty segments, the bars being of hard copper, eleven-sixteenths inch deep, insulated with mica. The points of commutation are 135 degrees apart.

The following is a short résumé of a set of tests upon one of the above machines:

Test for heating.—Duration of run at full load, four hours.
Heating of armature above the temperature of the room, 32° F.
Heating of fields above the temperature of the room, 32° F.
Bearings, commutator, and brushes, cool.

Insulation.—Insulation, while warm after running on full load.
Shunt field to core, over 1 megohm.
Series field to core, over 1 megohm.
Series field to shunt field, over 1 megohm.
Frame to bed-plate, over 1 megohm.
Armature to core,* 10,000 ohms.

Compounding.—After the four-hours run the following observations were taken to test the compounding:

Ampères.	Volts.	Speed.
202	80	400
130	81	400
60.......	80	400
0.......	82 (?)	400

For service on shore, where the drop in the lines is considerable, it is desirable that the machine should be somewhat over-compounded; that is, that the electro-motive force should be somewhat higher at full load than at no load. However, for ship work, in which case the mains are short and the drop inappreciable, the best plan is to have the compounding exact. It is probable that in the above case the speed rose slightly at no load, thus rendering the best observation faulty. The speeder, timed by a watch, could not be relied upon to within 1 per cent. The adjustable box in the shunt field allows an adjustment to correct for change of speed at a given load.

Efficiency.—Commercial efficiency at full load $= \frac{\text{electrical output}}{\text{work absorbed}} =$ 86.4 per cent.

FOREIGN PLANTS.

With a few exceptions, the practice in foreign navies seems to have been, during the past year, to adhere to types of the year before. Figs. 4, 5, and 6 represent a dynamo recently built for the British navy. The machine is of the Gramme type, with inverted horseshoe magnets, and is intended to be driven direct by a Willans engine. The magnet cores are of soft annealed wrought iron, 100 square inches in cross section; the armature core is built up of iron wire, the turns of which are insu-

---

*This low insulation was due to the shellac on the wire not being dry, and was afterwards improved to over one megohm by baking.

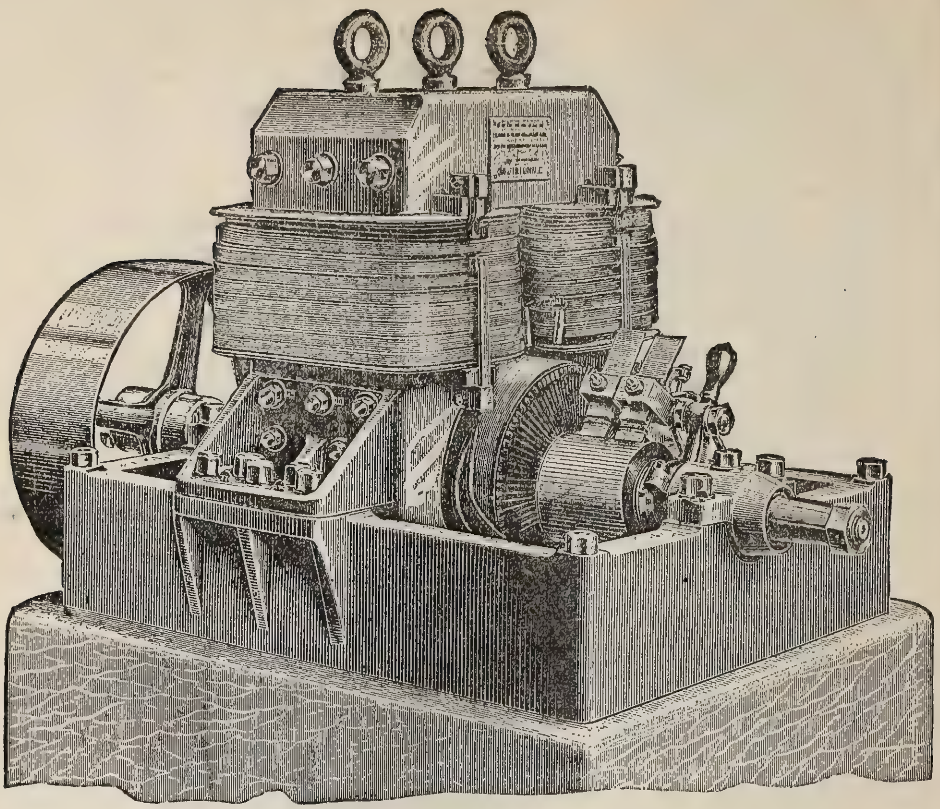
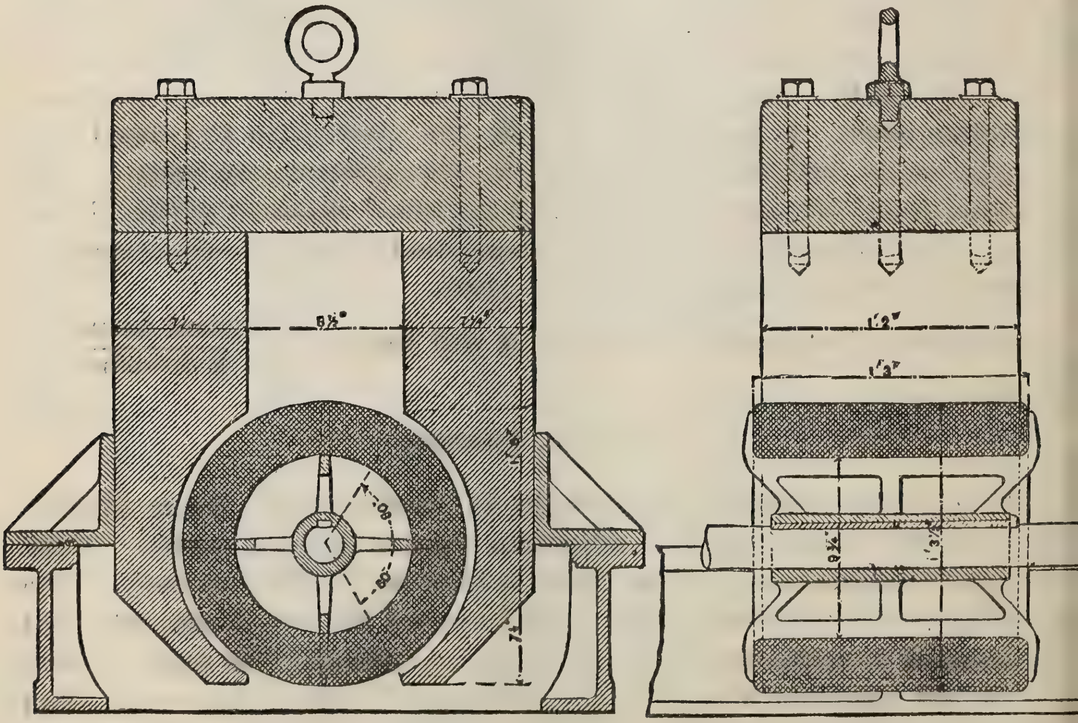


FIG. 4.



FIGS. 5 AND 6.

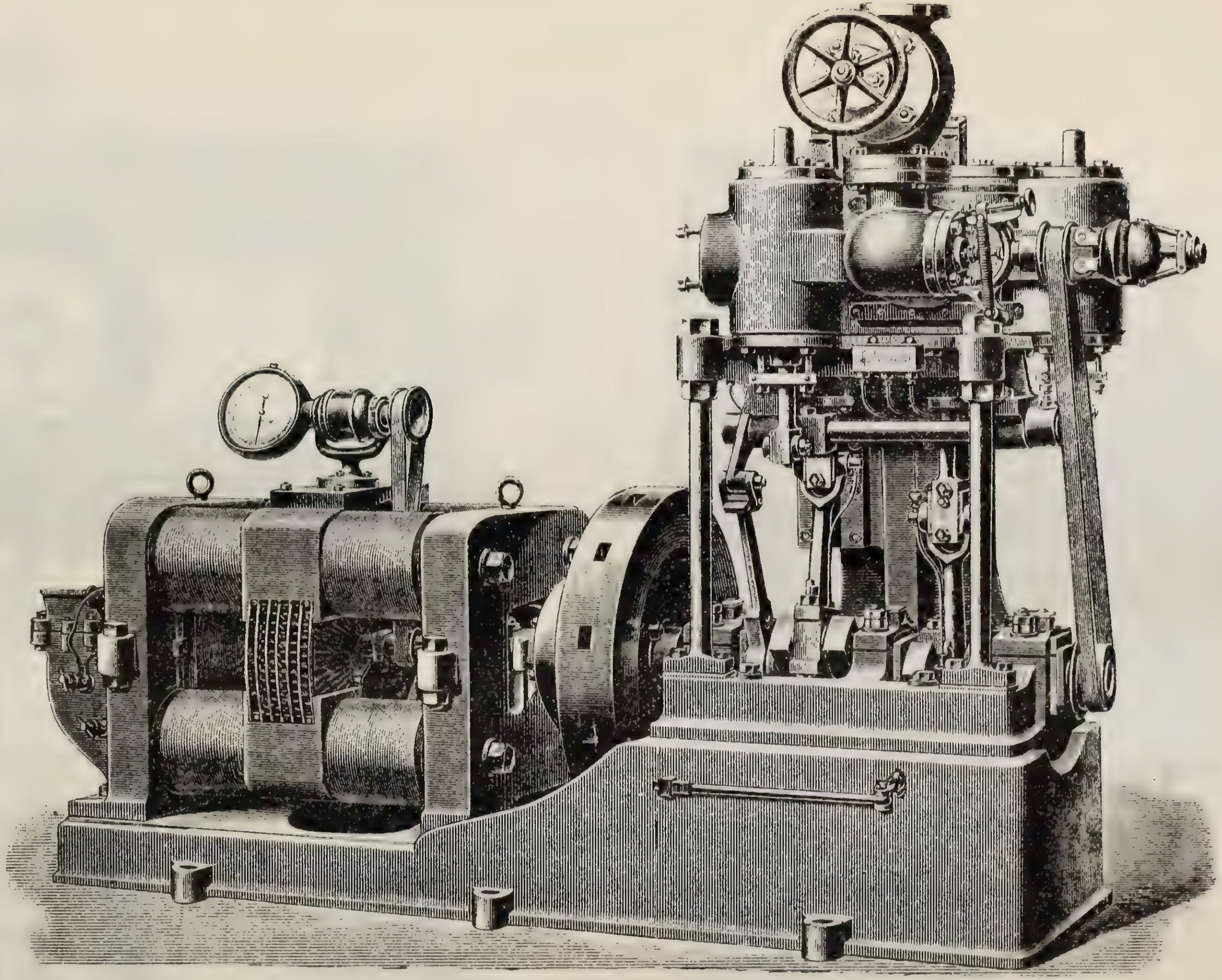


FIG. 7.—RAWORTH'S ENGINE AND VICTORIA DYNAMO.

lated from each other, supported on a metal spider. The following data will serve to give a clearer idea of the machine:

Number of sections in commutator		80
Resistance of armature (cold)	ohms	.018
Resistance of shunt field	do	18.6
Resistance of series field	do	.006
Number of turns of shunt-field wire		2,960
Number of turns of series-field wire		28
Number of turns in armature		160
Exciting power of shunt field in ampère-turns		11,400
Exciting power of series field in ampère-turns		5,712

The armature conductor is a cable of trapezoidal section, consisting of nineteen strands of wire, 64 mils in diameter, that of the shunt field being 83 mils in diameter, while the series winding is of insulated copper bars, three-fourths by one-fourth inch. Running at 460 revolutions, the machine is intended for an output of 200 ampères at 80 volts.

Fig. 7 is a view of a Victoria dynamo, having an output of 200 ampères and 65 volts, driven by a Raworth engine. The plant was intended for the Italian navy.

SEARCH-LIGHTS

General Information Series, Vols. VI and VII, discuss thoroughly the then existing plans of working search-lights. Now the problem takes on a new character. The naval compound dynamo is a reality, and with new apparatus it is well to reconsider the general problem.

Taking the case of a search-light requiring 50 ampères and 50 volts, to be maintained from an 80-volt compound-wound dynamo, the use of dead resistance to cut down the electro-motive force to that required by the arc naturally suggests itself. The fall in the dead resistance will be 30 volts, which with a current of 50 ampères means a loss of 1,500 watts, and the efficiency, or the ratio of *useful* power to that delivered to the dynamo shaft, would be 48 per cent., or somewhat less. Fortunately, this is not the true solution of the problem. Fig. 8 represents graphically the parts played by the series and shunt field coils in one of these machines. A is the final curve of the compound dynamo, plotted with volts as ordinates and amperes as abcissæ. This is the external characteristic of the machine. B is a similar curve, considering the shunt-field coils alone, and C is the characteristic using the series coils only. The sums of corresponding ordinates of B and C give the ordinates of A. In the diagram (Fig. 8), which represents an actual case, the resistance of the shunt coils was 5 ohms, and an extra resistance of 5.8 ohms was also in this circuit. Suppose that it is wished to run the search lights, using the spare dynamo. By putting more resistance in series with the shunt field by means of the adjustable box, a curve similar to B′ would result as the representation of the effect of the shunt coils, while C would remain the same. Thus a new characteristic, A′, would result. The point necessary for setting the arm of the resistance box, once determined, need never be changed when it is desired to use the machine in this way. Thus, if only one lamp is in use, there will be an E. M. F. of about 50 volts at the terminals of the machine; if two, about 53 volts. In either case 2 or 3 volts might be taken up in drop through dead resistance and thus furnish a means of regulation, independent of the shunt-box, which remains set at the point originally determined. This small dead resistance would serve to steady the light and prevent the short-circuiting of the machine.

What would now be the efficiency of conversion? No extra heating would result beyond that produced under ordinary working at this diminished power. It is safe to assume that the efficiency of the machine at this load is 75 per cent., and this is the figure that has already been used in the former part of the discussion. The percentage loss in the fields becomes less when working at 50 ampères according to the curve A′, than when working according to A. The efficiency of the machine will therefore be at least 75 per cent., and deducting for the loss in dead resistance, the commercial efficiency of the whole electrical combination up to the lamp terminals would be about 70 per cent., as against 48 per cent., under similar conditions, using only dead resistance in the external circuit to reduce the electro-motive force at the lamp. In the above discussion a 200 ampère machine has been kept in mind. The showing in the case of the smaller style (100 ampère) would be somewhat better, and while the former could, in this way, work four search-lights in parallel with ease, the latter could run two equally well. Further, such an arrangement is as well adapted as an ordinary compound dynamo to the maintenance of a steady arc. The operation of striking the arc, even when a resistance is in series with the lamp, is hard on a dynamo, and still more so on the high-speed engine. These difficulties can be entirely avoided, a quicker focusing effected, and every operation of the arc rendered more certain by such a lamp as that represented in Fig. 9. The ordinary search-light, regulated by hand, is slightly modified. The current from the lower carbon traverses the coils of the solenoids B before passing out by C. These attract the armature A, rigidly attached to the lower carbon-holder, which has a play up and down, overcoming the pressure of the spring D. Thus when no current is passing the carbons are in contact; but the instant the lamp is put in circuit the arc forms, and in the working position, with the armature drawn down, the lower carbon will be as firm as if its holder were solidly attached to the frame, as in the ordinary search-light. Further regulation may be performed by hand. Should the arc be broken the lower rod would move up under the action of the spring, and upon the carbons being further approached by the hand-screw the arc would be formed instantaneously as before. An air dash-pot, not more than three-fourths of an inch long by three-fourths of an inch in diameter, and not shown in the figure in order to avoid complication, would form sufficient cushioning to

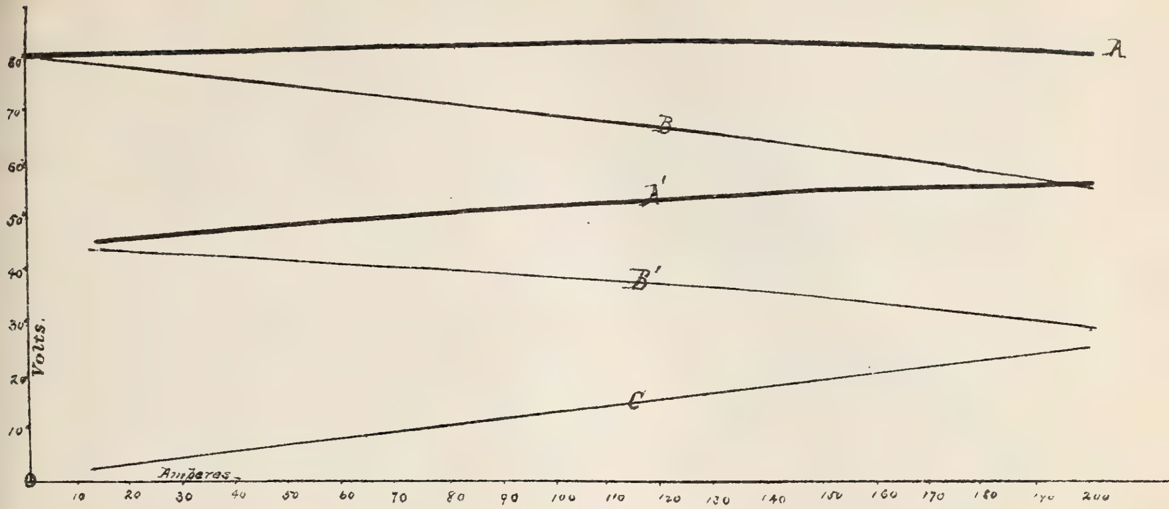


Fig. 8.- Characteristic Curves of Marine Dynamo under Varying Circumstances.

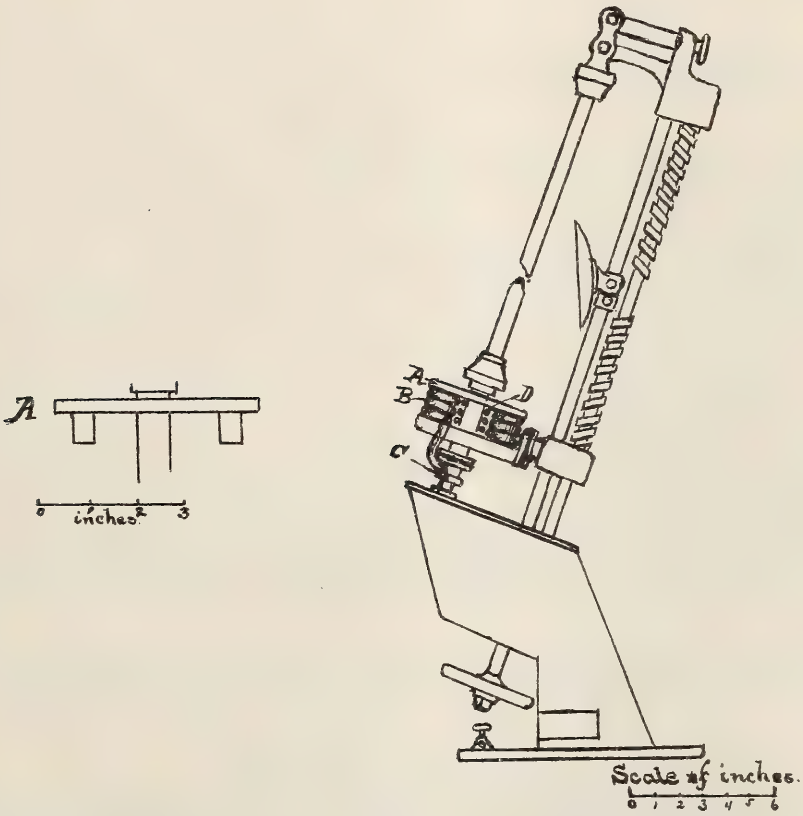


Fig. 9.- Modified Lamp for Search Light.

the motion of the movable parts. To my knowledge no search-light has been made on this principle. A practical test would be a very simple matter, as the only alteration necessary in an old lamp would be that of the lower carbon-holder. The additional obstruction offered to the light would be inappreciable, as the solenoids are placed in line with the other mechanism. Should it become necessary, in an emergency, to run search-lights and incandescents at the same time by one dynamo, this form of lamp would cause no unsteadiness in the incandescents. In this case, of course, the machine would have to be run as usual for incandescent lighting—at 80 volts. In order to provide for both contingencies, such an arrangement of the resistances as that shown in Fig. 10 would answer the purpose well. Fifty volts could then be maintained at the lamp, if the electro-motive force of the machine were 51, 52½, 55, 77½, 80, 82½ volts.

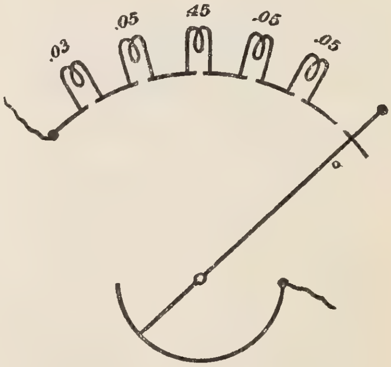


Fig. 10.–Diagram of Resistances.

A thoroughly efficient search-light should also contain within itself the possibility of being transformed into an automatic focusing lamp, so that it might give a continuous, steady illumination, without constant attendance, when so desired. To meet this need, Sautter, Lemonnier & Cie., of Paris, have lately introduced a combination lamp, in which the screws ordinarily used for separating and approaching the carbons can not only be worked by hand, but, by setting a catch, the hand regulation ceases and the arc becomes controlled by compound electro-magnets, contained within the casing which forms the base of the lamp. This governing is accomplished by having the upper and lower screws connected at their junction by a sleeve, which allows the lower screw and carbon-holder a small amount of movement up and down. The whole of this part of the apparatus is controlled by the electro-magnets, when the lamp is being used automatically.

Experience gained in the recent Spanish manœuvres (see page 448) places in doubt the utility of the search-light on torpedo-boats.

ELECTRIC MOTORS.

No subject in the application of electricity is more inviting than that of the introduction of noiseless, compact, clean and cool electric motors in the place of the small steam-engines on board ship. But so pleasing is the contrast in favor of the motor that we are apt to forget to take due consideration of all of the points on both sides of the question.

For the sake of definiteness, consider a cruiser supplied with four hundred incandescent fixtures, with a total of 6,000 candle-power; four search-lights, and, without any motors, let the vessel be supplied with duplicate units, each comprising a dynamo with an output of 200 ampères at 80 volts, driven direct by a high-speed engine. Not as much information bearing upon this case can be obtained from the operation of central stations on shore as is generally supposed. In practice on shore a plant is erected, not only to suit present needs but with careful calculations upon future developments. The promoters of the undertaking have to supply, in general, five classes of customers—stores, which close early in the evening, or leave only their window lights burning until late; theaters and other public halls, which require their illumination until midnight; offices, which need light early in the evening only; private residences, the demand of which reaches a maximum at about nine in the evening; and lastly, power necessary for motors. This last is a great boon to the central station, as it fills in, to some extent, the idle, or nearly idle, hours of the plant. The diagram (Fig. 11) represents a twenty-four hours' run with power as ordinates. The needs for lighting would be represented by some such curve as L, varying slightly for different seasons of the year. Evidently, only about one-third of the available energy is being utilized. Let AB represent the maximum electrical horse-power of the plant. Motors are in operation mostly during the day, and if power can be rented for such work, the curve of demand may have some such form as that of M. Under these circumstances the total power required during the day will be given by the curve P, and a very large percentage of the possible output will evidently be utilized, little of the capital will be lying idle, and the business of supplying current for motor work and that of supplying current for incandescent lighting will go hand in hand, each assisting the other in becoming an economical success.

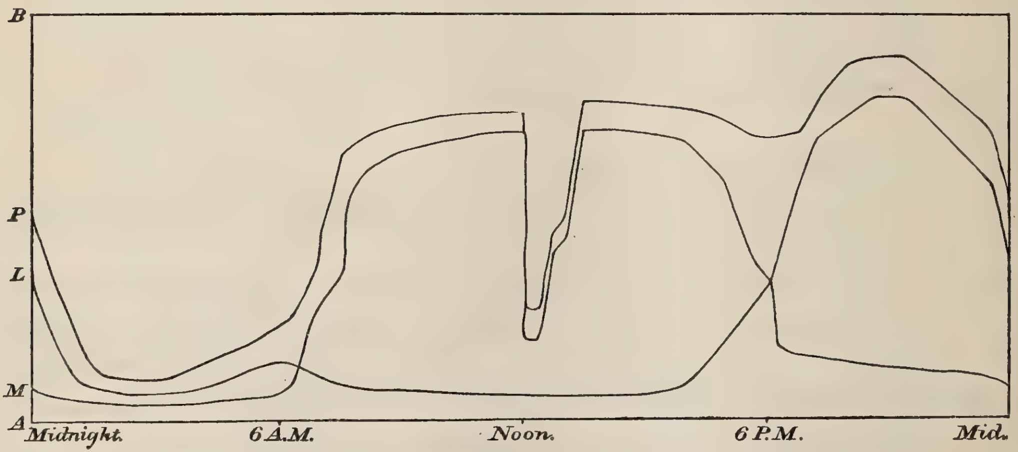


Fig. 11.

In Fig. 12 the full line represents the similar problem on board ship. Only a small portion of the total power possible is used and, apparently, there exists a very large field for the use of the electric motor. This would unquestionably be the case if the requirements for motor service on board ship were the same as on shore. In selling light from the shore station, the diagram of which is given in Fig. 11, it would not only be safe to contract for delivering an amount somewhat greater than the total output of the plant (as all of the consumers will not be using current at the same time), but also to sell current for motors equal to about the total capacity of the station. A margin of power will still be left for safety. On shore, motors are used most during the day and thus help to fill up the idle, or nearly idle, hours of the plant. Those on ship-board may be divided into two classes—those essentially connected with the fighting qualities of the ship, and those intended for the service of the ship, as such. To the former class would belong gun-training motors, ammunition hoists, etc., while the latter class would embrace steering motor, blowers, ash hoists, and windlass motors. The former would be used for exercise most during the day-time, but only for a short time each day, while their real purpose would be fulfilled in time of action. Of the latter class, the steering motor and blowers are the only important ones that would be in frequent use, and at sea these would be as necessary at night as in the day-time. The windlass motor would be used probably more in the day-time than at night, but only for short intervals, and then it alone would require nearly all of the electric power that is now supplied on board men-of-war to work it.

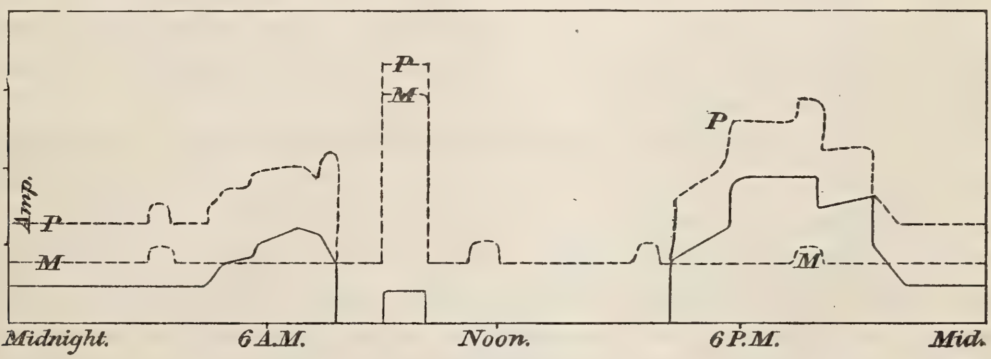


Fig.12.

Should it be desired to replace by electric motors the many small steam-engines on such a vessel as the one already spoken of, the following list will give some idea of the power that would be necessary for the different classes of work:

	H. P.
One steering motor	15
One anchor motor	40
Two gun-training motors, at 10 H. P. each	20
Four ammunition hoists, at 2 H. P. each	8
Four blowers, at 3 H. P. each	12
One ash hoist	2
Total	97

I consider this figure well within the limit of what would be required.

The dotted line M in Fig. 12 gives a rough idea of the power that would be required for motors on an ordinary day. Evidently the power line is raised almost as much during the night hours as during those of the day. Without enlarging the plant, and thus introducing more idle power in the central station, it would not only be impracticable to use the windlass motor, except when the plant was otherwise nearly idle, but it would also render it an impossibility to use the search-lights without running them on a machine feeding also on parallel distribution. An increase of the central plant becomes necessary, even for the requirements of ordinary service. The motors which would be used on board ship are essentially connected with the idea of an engine of war, and we must consider also the demands for current during a night engagement, when the most power will be needed. Lights will be necessary on the gun-deck, berth-decks, orlops, in engine room, fire-room, sick-bays, dispensary, magazine, shell-rooms, etc. Fig. 13 represents the state of the case. Ordinates of I indicate the power that must be allowed for the illumination of the interior of the ship, while S represents one machine reserved for search-lights. The total power that may be required simultaneously (without any motors) is given by the line W, which leaves only a margin somewhat greater than 100 ampères within the total power now available.

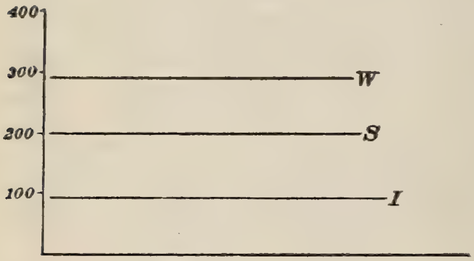


Fig. 13.

The motors which might be used on board ship would be convenient under any circumstances, but if they are to be of service at all on board a man-of-war, they must be ready for work in action, when the saving of man-power is most important. Thus, in the above list, the gun motors must all be ready for simultaneous duty at their full power, the steering motor would be absolutely necessary, the blowers never more needed, while the hoists for both ammunition and ashes would also be required. Even the windlass motor might be of service in rendering assistance to a disabled vessel, or for other purposes. For motors, therefore, there must be supplied at least 57 horse power of electrical energy. We have seen that within 110 ampères of the whole power of the plant is already necessary in time of battle. Hence, in order not to cripple the installation, there must be added to the present illuminating and search-light plant—consisting of two 30 H. P. engines and two 22 H. P. dynamos—three 30 H. P. engines, three 22 H. P. dynamos, and thirteen motors, aggregating 97 H. P., and mains for the same; the last to replace thirteen steam-engines of equal power and piping for the same.

In times of peace there is no question as to the desirability of small wires, instead of steam-pipes; silent working, instead of noise, and all of the other well-known advantages of the motor. But is an exclusive or general introduction of electric motors most to the advantage of the service of the ship as an engine of war? If a steam pipe is struck by a shot, damage is done which may cause other mischief and which is difficult to repair, whereas electric mains can be quickly renewed; the mains require less room than the steam-piping and are, therefore, less liable to accident. If either class of machine is struck by a projectile it is placed *hors de combat*, but the electric motor much the more easily. One shell reaching the dynamo-room and exploding there would probably irreparably disable the whole plant, as, while running at full load, a cross in the armature or magnet windings, caused by the impact of a very small projectile would soon leave little but charred insulation and bare wire over the part of the machine affected. Thus, not only would the ship be in total darkness, but every auxilliary engine would be useless. With steam-engines this could not be the case, unless the main boilers were all exploded.

Two methods may be suggested for overcoming the difficulty: First, by having two duplicate dynamo-rooms, each containing half of the entire plant necessary for all purposes, both well below the line of protection, containing not only duplicate plants, but duplicate switch-boards and connections to mains. Then, in action, the machines at both stations would be connected in parallel on the circuits required. If one station is disabled, some safety fuzes may be burned out, but the general illumination would not be materially interfered with; the search-light machine could be run up to 80 volts and a resistance placed in series with the arcs, in order to obtain ten horse-power more for parallel distribution, and the less important consumers of current could be shut off.

Second, by storage batteries, which would be of the greatest service on board ship were it not for their rapid deterioration under such use, their weight, their great primary expense and cost of renewal, and the fact that none have as yet, to the writer's knowledge, been tried under the conditions of ship use for a sufficient length of time to warrant drawing conclusions. This question will be more fully considered later on.

One great objection to the first plan is the space necessary. The motors and stores would require about as much room as the corresponding steam-engines. The addition to the central plant would require about 75 square feet of floor space for dynamos and engines, and 110 square feet to provide for space for attendance, switch-boards, etc., a total of 185 square feet for additional dynamo room. The efficiency of the two systems, the present steam and a corresponding electrical one, would be about the same as long as both are in actual operation. In any case special circuits would, of course, have to be run, as it would hardly be in keeping with good practice to install a 10 or 20 horse power motor on a circuit which requires ordinarily 3-horse power for a few hours every evening and perhaps one all night. The motor circuits would all be brought to the dynamo-room switch-board.

STORAGE BATTERIES.

The above discussion naturally brings us to the consideration of storage batteries, which present many tempting points. If their use were an assured success on board ship (which is not the case even on shore, except in special applications) many of the difficulties of the problem of ship lighting and auxiliary motor power would be removed. Thus, by placing such a battery as low as possible in the ship a reserve lighting and power station could be obtained entirely out of reach of the enemy's fire. In time of peace nearly all the vacant space could be filled in the diagram (Fig. 12), included in the hours of the regular night run, and then, after shutting down in the morning, the battery could automatically feed motors and lights used for any work whatever. A good storage battery would also solve the problem of working search-lights efficiently without disturbing the rest of the system, and would be very handy for launch search-lights. For, instead of carrying a dynamo, an extra engine, and coal to supply its power, it would be necessary only to carry the cells, conveniently stowed away under the seats, doing the same work and not drawing upon the boat's boiler power, thereby consuming coal and reducing the speed.

The lightest and most efficient secondary batteries made of lead and lead compounds now on the market give one horse-power-hour for about 80 pounds weight.* The statement in General Information Series, No. VII, in which it is announced that "Experiments have shown that a horse-power can be maintained for eight hours with a total weight of 150 pounds of battery and motor, and much better results are claimed," would therefore seem to be an error (probably typographical). In the best forms of the grid storage batteries not more than one-third of the weight of the plates is of service in the chemical transformations, so that it seems probable that in the not distant future we may have a better and higher form of cell.

The French submarine torpedo-boat *Gymnote* is fitted with alkaline accumulators of the Desmazures type. In these the solution is zincate of potassium; the positive plate, iron wire gauze; the negative, a porous copper plate, formed by compressing the electrically deposited metal. During the charging, zinc is deposited on the iron gauze and oxygen is absorbed by the copper plate. In discharging, the zinc is redissolved, combining with the oxygen liberated from the copper plate. Thus the cell seems to be perfectly reversible in its operations. Tests have given good results. According to Mascart, the efficiency is 65 per cent., while the weight in the case of the cells tested by him was 81.5 pounds per horse-power-hour.

The *Gymnote* is supplied with 564 cells, each weighing 38.5 pounds, making a total of 21,710 pounds. The capacity is 345 horse-power-hours; that is, 63 pounds weight per horse-power stored, or about 87 per horse-power delivered. The liquid gives off no fumes; the cells are made of tinned sheet steel, and may be sealed for portable work. The motor used is multipolar, having sixteen poles arranged around a ring armature. It is connected direct to the propeller, and is run at two hundred revolutions per minute. The motor weighs 4,400 pounds, and at 220 volts (probably at the armature poles), with a current of 220 ampères, gives 60 horse-power, or 10 watts to the pound of machine. The efficiency is something under 80 per cent. One charge of the cells allows for a speed of 10 knots for six hours. (For further description of the Gymnote, see p. 453.)

---

* References, Johns Hopkins University Tests, Mascart.

The Edison Company has lately built a motor (see Fig. 14) for a controlled fish torpedo. It is a series machine, designed for 22 ampères and 1,100 volts (at the generating station). It has developed 25 horse-power running at 1,400 revolutions, but sparks badly, which is hardly, to be wondered at, as the motor, including gearing to reduce the speed to that of the propeller, weighs only 764 pounds, or 1 pound weight for 24 watts output.

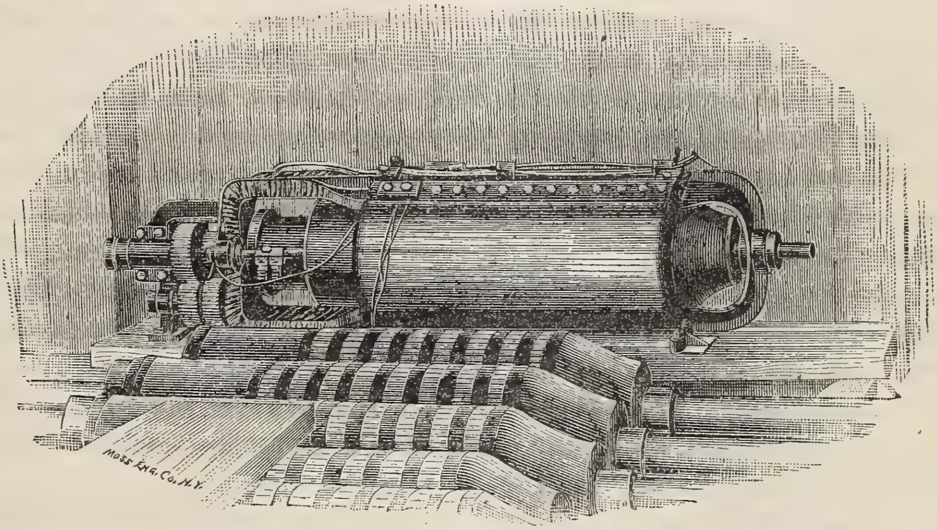

MOSS ENG. CO. N.Y.

FIG. 14.

From what has been said it seems that there are a number of uses to which electric motors may be put on board ship with advantage and economy; but the general displacement of all auxiliary steam-engines and the entire substitution of electric motors is regarded as a question of the future, dependent upon the introduction of a storage battery lighter, more efficient, and more durable than any known to the writer, or, possibly, of more compact and economical machinery and apparatus.

The extent of this paper does not permit the consideration of the numerous minor yet important applications of electricity on shipboard, such as gun and torpedo firing apparatus, tell-tales, telegraphs, and call-bells. The first might be operated by currents from the dynamos; but, inasmuch as an E. M. F. of a few volts only is necessary, small batteries of cells, constructed to prevent the spilling of the liquid and conveniently stowed, are obviously better adapted to all of the above-mentioned purposes.

THE USES OF ELECTRICITY AT NAVAL SHORE STATIONS.

To the requirements necessary in the most advantageous employment of electricity in small manufacturing districts must be added others, which have direct bearing upon the nature of the work performed, and upon the fact that the navy-yard exists for the building, equipment, and repairing of vessels of war. Thus, while a central station—supplying current for both outside and interior lighting and electric motors—telephones, fire-alarm systems, telegraphs, and watchman's time-detector service, must all come within the equipment of a thoroughly modern navy-yard, the first, in particular, will need many important modifications. No other application of driving and driven machinery has undergone so rapid a change in the past few years as has the general method of applying the power in a central electric lighting station. The large stationary engine, lines of shafting, countershafting and belting, have been replaced in most of the new installations by systems of distinct units, comprising each only one or two dynamos, driven by some such high-speed engine as the Armington & Sims, Ball, Buckeye, Ide, Safety, or Straight Line, whose excellent qualities have been developed mainly in answer to the demand created by this particular line of work.

For isolated plants in large cities, where floor space is valuable, heavy machines of larger size, wound for slow speed, are often driven direct from a high-speed engine. Floor space has a certain value everywhere, and as there is no inherent reason why good slow-speed dynamos should not be built, more general disuse of belting for even shore work is only a question of time. The advantages of a direct driven machine—saving of space, less friction, less wear in the bearings, and saving due to there being no belting to supply and keep in repair—are apparent.

The principal points to be provided for in lighting a navy-yard are: Outside lighting, lighting for shops, offices, and quarters of officers, motor applications, and arrangements for temporary circuits. These heads will be treated separately.

Outside lighting.—For outside lighting, in such a district as that under consideration, the arc light is productive of the best results. This necessitates the employment of dynamos of high electro-motive force, and every precaution must be used to guard against accident—a prevention that often receives insufficient attention in commercial lighting. Even in the station, where the attendant will probably be a seaman-gunner, whose training has been with the low-pressure current for incandescent lighting, special arrangements must be made to render an accident due to shock next to impossible, and this can be done. The great majority of cases of death by the electric current occurs among ignorant men, whose lack of knowledge of the subject of electricity itself leads them to carelessness. An arc-light circuit, with its high electro-motive force—over a thousand and often thousands of volts—should be treated with great respect. Switches and switch-boards should have all metallic parts in connection with the circuit so protected as to entirely prevent a person's touching any of them.

Under-ground circuits for arc lighting are very expensive, and few cities furnish reports of their successful working, while in most instances the attempt at using them has resulted in failure to a greater or less extent. Therefore it is advisable to run these wires overhead, never, however, using a building as a point of support, except where the wire is to enter the building. The lamp-posts, if made of iron to give a more ornamental appearance, should have two insulating joints to effectually prevent the possibility of an earth. By thus breaking the metallic continuity of the post, not only will the system be improved as regards insulation, but the trimmer will be protected against the danger due to an earth if the current should accidentally be on the lamp when he touches one of the carbon-holders. The casings and frames of the lamps should be insulated from the circuit and every lamp should be provided with a switch.

Shop lighting.—Certain shops, such as foundries, forges, ship-houses, and machine-shops for heavy work, can be best illuminated by arc lights; while others, as machine-shops for fine work and pattern-shops, can be most efficiently lighted by incandescent lamps. Still others will require both. But the plan of running incandescent lights on arc circuits, in order to overcome the necessity of two distinct sets of mains, is considered inadvisable. We all come to regard an incandescent lamp as harmless—a convenience to be used in residences and to be handled even by children. To place one of these lamps before a workman, with its connections at a thousand volts above the potential of the earth, hardly seems a plan commended by its safety.

Offices and quarters.—The offices and quarters of officers should, of course, be lighted by incandescence, but in order to accomplish this without great waste of output in copper and constant waste of energy, it becomes necessary to distribute at a higher pressure than that used on board ship and to further decrease the loss due to resistance of the lines by employing the three-wire system of distribution. Lamps of 110 volts seem to give the best results. By using the three-wire system and assuming that the neutral or middle wire is of the same size as the two mains, the copper used in conductors will be as $\frac{1}{2}+\frac{1}{2}+\frac{1}{2}$ to $1+1$, or as 3 to 4, in favor of this method of distribution; or, the areas covered from one station, using the same cross section of conductor per lamp and the same loss in the mains, will be as the squares of these numbers in favor of the three-wire system. In some cases, however, the distances will be too great for the advantageous use of this method of distribution, and then the alternating system with transformers may be used. One great drawback to this is that there is no alternating current motor really on the market, though we read of apparently successful tests made upon them in this country and abroad; but no tables of data or detailed descriptions of the experiments are published, and the question of the commercial value of the machines remains in doubt.*

Motors.—An excellent field exists for motors in the future possibility of using them for light portable drills in ship-building; for heavy overhead traveling cranes in large machine-shops, in the place of those operated by cotton rope—an application which commends itself on account of its extreme simplicity; as substitutes for small portable steam-engines, and to furnish power for derricks.

Temporary circuits.—Temporary circuits will become necessary in such emergencies as coaling or provisioning ship at night, or working at night on a vessel in dry-dock, and might be desirable in order to furnish a vessel with light when her own lighting plant can not be operated by reason of repairing or overhauling her boilers, dynamo-engines, or dynamos; on account of being in dry-dock, or for other reasons.

For the first-named purposes it will be necessary to run a temporary line of a few arc lights, introducing it in one of the regular circuits at the nearest convenient point. The line and lamps can be kept safely out of reach of every one by supporting both by portable tripods. It would be more difficult to provide a temporary circuit for the second kind of work, as the mains would be heavier and more clumsy to handle, and putting in an extra circuit might overbalance the system. The main circuits intended to receive the extension would also have to be of greater cross-section, in order to provide against overheating, and the potential at the ship would have to be reduced to 80 volts by means of dead resistance. The efficiency of this branch would be about 60 per cent. As a rule, the buildings requiring incandescent lights are not on the water front, and the temporary circuit would have to be very long, would require too much labor to put it up, and most of the time would be useless and in the way. Some other plan must be looked for. A special two-wire circuit might be run for this work, and one of the spare machines arranged so that its compounding could be changed to 90 volts, which would be a simple matter. The long circuit necessary operates against this plan. The need of a good storage battery again presents itself. By having sets of cells arranged on trucks all temporary circuits could be avoided, except the short one to the arc lamps themselves, or from the dock to a ship alongside. This would, however, at present be a source of too great expense to pay for its utility. Two other plans that present themselves are, first, to have a small portable steam-engine and an 80-volt dynamo connected direct; second, a constant-current motor coupled to an 80-volt constant potential dynamo; all machinery in either plan mounted upon a covered truck. Such an arrangement—exclusive of truck—would weigh about 2,000 pounds for 10 horse-power, and would give an efficiency of double conversion between 70 and 75 per cent. Its advantage would be that the motor could be put right on the arc-light circuit; the disadvantages, primary cost and high potential at the motor.

---

*Since the above was written, alternating current motors have been placed upon the market, but the writer has had no opportunity to see them in operation.

In conclusion, the writer wishes to acknowledge his indebtedness to the Naval Inspector of Electric Lighting for his aid and many valuable suggestions in the preparation of this paper.

4.

REMARKS BY THE NAVAL INSPECTOR OF ELECTRIC LIGHTING.

Commander R. B. Bradford, U. S. Navy,
Naval Inspector of Electric Lighting.

The complete papers by officers who are associated on duty with the writer, in connection with the installation of electric lights on board naval ships, at navy-yards, etc., leave little to be said in regard to the progress of electric lighting during the past year.

SHIP-LIGHTING PLANTS.

Messrs. Sautter, Lemonnier & Co., Paris, France, the owners of the Mangin mirror patent, and other patents of similar appurtenances, are probably the largest manufacturers of electric lighting apparatus for military and naval purposes in the world. The productions of this firm clearly indicate the progress of events abroad in the application of electricity as a medium of light for war uses.

On page 343 of General Information Series, No. VI, is described a dynamo and engine built by this firm for the French battle-ship *Indomptable*, of 7,200 tons displacement. It is illustrated on page 212 of General Information Series, No. VII. Two of these engines and dynamos, the latter of 66 volts and 150 amperes, were supplied to the *Indomptable*, giving a total output for the ship of 19,800 watts. This type of dynamo is now made to give a current of 70 or 80 volts and 150 amperes, with a speed of 350 to 370 revolutions per minute. The total weight of the new dynamo, its engine, and a foundation common to both, is 7,040 pounds.

The *Admiral Baudin* and type, battle-ships of 11,300 tons displacement, are supplied by this firm with two sets of engines and dynamos, very similar to those of the *Indomptable*. The dynamos have six poles instead of four, showing a tendency to extend the multipolar principle; they are of 70 or 80 volts, the pressure being subject to regulation between these limits, and 300 amperes, giving a total output of 48,000 watts for each ship. The weight of each plant is 8,800 pounds, and the revolutions per minute 350 to 370. The engines, except in size, are in every way similar to those of the *Indomptable*. Each plant occupies a space 9 feet long, 3 feet 5 inches wide, and 5 feet 11 inches high.

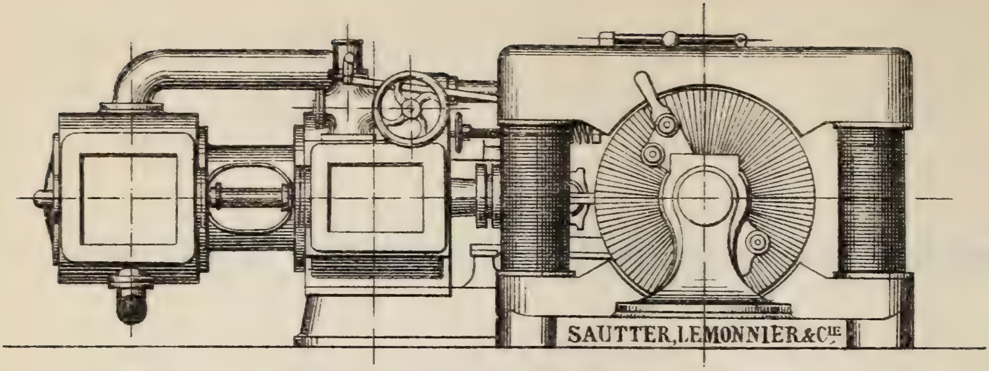


Fig. 3.

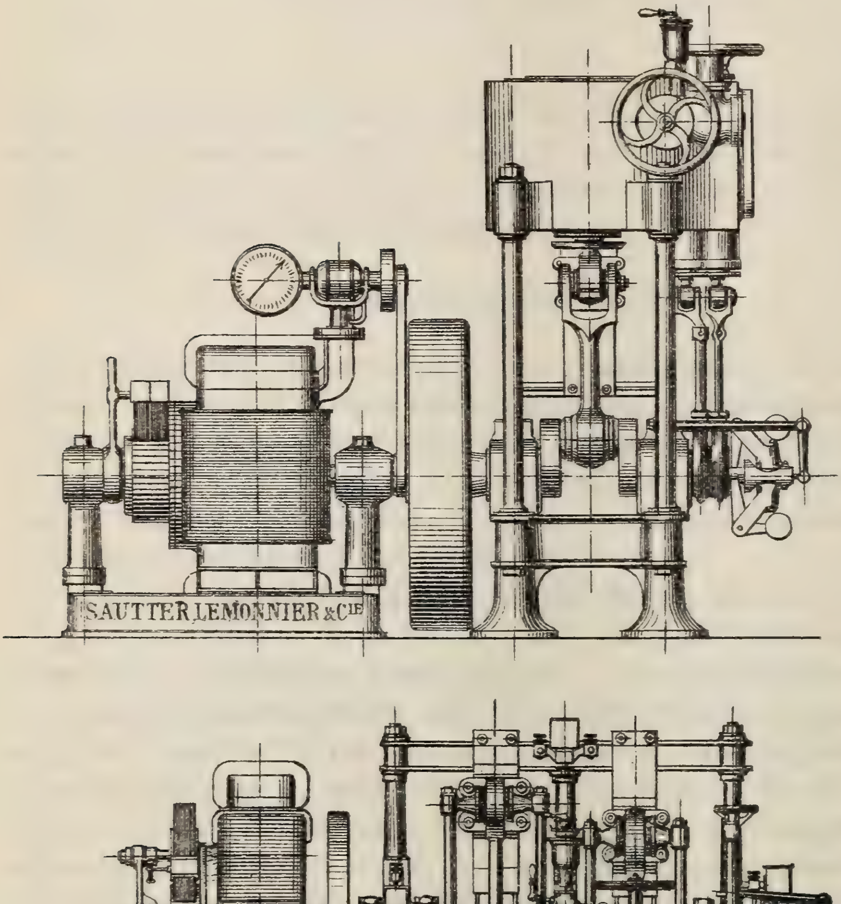


Fig. 2.

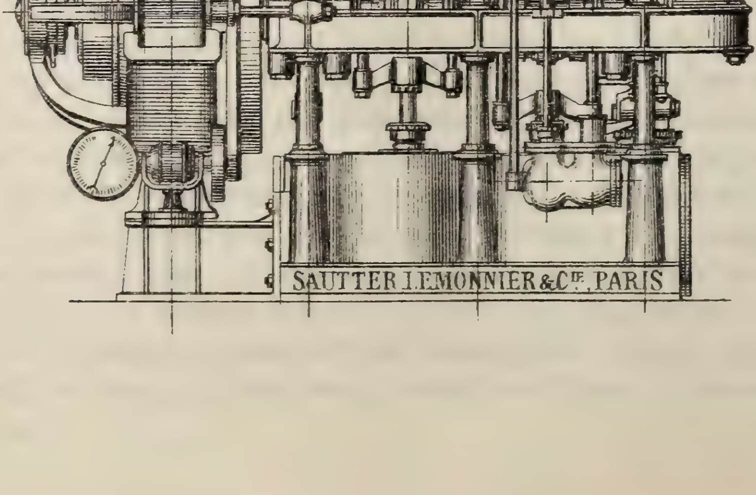


Fig. 1.

Fig. 1 shows another plant manufactured by this firm, the chief characteristic of which is the retention of a vertical engine with a decreased total height of plant. This type has been installed on board of the *Troude* and class, protected cruisers of 1,877 tons displacement. The dynamo has three sets of poles, called by the makers "triplex," and is of 70 or 80 volts and 150 amperes, with 350 to 370 revolutions per minute. The engine has the cylinders placed at the bottom with the shaft centrally located and the connecting rod above it. This plant is light and compact, its weight being 5,940 pounds, length 6 feet 8 inches, width 3 feet 5 inches, and height 4 feet 7 inches.

Another type of plant, shown in Fig. 2, is installed on board of the armored coast-defense ship, *Tonnerre*, of 5,700 tons displacement. As in the case of the *Indomptable* the dynamo has two sets of poles, called by the makers "duplex." Different sizes are constructed, all having a pressure of 70 to 80 volts, with 350 to 370 revolutions per minute, and each of 150, 200, or 300 amperes. The engine has a single vertical cylinder. The largest sized plant weighs 7,040 pounds and occupies a space of 6 feet 8 inches long, 3 feet 5 inches wide, and 5 feet 8 inches high.

Still another type of plant, shown in Fig. 3, is installed on board of the protected cruiser *Davout*, of 3,027 tons displacement. The chief point of interest connected with this plant is the introduction of a two-cylinder tandem engine, enabling it to be installed in places of but little height. The voltage and revolutions of the dynamo are the same as those of other dynamos already mentioned; two sizes are manufactured, one of 150 and the other of 200 amperes. The dimensions of this plant are length, 7 feet 10 inches; width, 5 feet 5 inches; and height, 3 feet. The weight for the 150-ampere plant is 5,940 pounds, and for the 200-ampere plant, 6,380 pounds; the same engine is used for the latter as for the former, a higher steam pressure being required. The steam pressure required for ship and boat electric-lighting plants manufactured by Sautter, Lemonnier & Co. varies from 30 to 105 pounds, 75 and 90 pounds being most frequently demanded. The great reduction in size, weight, and cost of plants employing a high steam pressure has caused the latter to increase rapidly. All dynamos are compound wound.

The chief lesson to be derived from these new designs is, that manufacturers must be prepared to supply plants that can be contained in such spaces on ship-board as are available for them. The U. S. S. *Charleston* affords an example of the necessity of different plants even in the same dynamo room. The room is located forward under the armored deck, and on account of the sloping of the latter it was found necessary to use a horizontal engine to drive the dynamo nearest the side of the ship. Accordingly, an Armington and Sims two-cylinder double engine, with cylinders 7 by 5 inches, was used, the other two engines being vertical compound of the Allan type.

CARE OF SHIP-LIGHTING PLANTS.

Officers in charge of these plants must not rely too much upon tachometers and meters. They are delicate instruments at best and liable to get out of order. The best meters can not be installed on ship-board, as they contain permanent magnets or are dependent upon the action of gravity. Every occasion possible should be embraced to compare and calibrate both volt and ampere meters. Another fruitful source of trouble with lighting plants is the neglect of the automatic engine governor. Both this and the valve should be overhauled at least every month, carefully cleaned, freed from all oil gum, and then well lubricated.

SHIPS' COMPASSES.

It is an unfortunate fact that the most important instrument used for the guidance of ships, the mariner's compass, is often disturbed and sometimes seriously affected by the electric-lighting plant. The plants in the Roach cruisers are placed on the berth deck, and for the most part aft, where they may very probably affect the compasses. The plants for the ships next designed were also intended to be similarly located, but at the earnest and oft-repeated solicitation of the writer they were all eventually placed below the armored deck, and generally forward. It is the present practice of the Chief Constructor to locate the dynamo room forward and well down near the bottom of the ship, where the disturbing effect of the dynamos is not likely to reach the compasses. Recently a lecture was delivered before the Institution of Electrical Engineers, London, by that eminent authority on both compasses and electricity, Sir William Thompson, from which the following quotations are made:

> When a continuous-current machine is used, the danger of producing an error on the compass can be avoided by using two wires close to one another, but these wires should be well insulated from the ship's side. If in any way (two points of) one of the wires is brought in contact with the iron of the ship there may be no change observable in the lighting, but the current may produce as much error on the compass as it would if there was only a single wire.
>
> The following points should therefore be attended to in all cases of lighting ships by electricity:
>
> First. With continuous-current machines two wires, well insulated, should always be employed.
>
> Second. The insulation of the wires should be tested periodically; if any connection with the iron of the ship is found the fault should at once be made right. * * *
>
> What makes this question of the greatest importance is that the error may be produced without ever being detected by the officers of the ship. On board ship the errors of the compass are usually determined during the day, in the morning and afternoon, but the electric light is only used at night. The captain may therefore carefully determine his errors every day and set his course quite correctly; but at night, when the electric light is turned on, the ship may be going several degrees off her proper course, although she is being correctly steered by the compass.
>
> In connection with the lighting of ships with electricity there is another point which should also be attended to—that is, the position of the dynamo. If it is placed

near an iron bulkhead, the upper end of which is near the compass, the bulkhead may become magnetized by induction so powerfully that it will produce a considerable error on the compass. * * *

The precautions for security which I have to suggest are—

(1) The use of the two-wire method exclusively (unless, which is now rarely the case, alternate currents are used).

(2) A differential galvanometer on the two mains for the lighting current to show approximate enough equality of the out-going and in-coming current. A rough and cheap instrument (on the old telegraph "detector" plan) would, I believe, suffice, and would be valuable for the electric-lighting system (independently of the compass question) to give timely warning of any faults or accidental contacts or failures of insulation sufficient to cause any considerable difference in the strength of the currents carried by the two mains.

(3) Care that there is not magnetic "leakage" from the dynamo (as practical men, guided by Farraday's ideas, theory, and language, have now taught the scientific world to call it) enough to produce any compass disturbance of practical moment. Captain Creak, speaking at the end of 1885, in the Society of Arts discussion, said that in one ship the direct compass disturbance produced by the generating machine was "felt through a distance of 55 feet," and across iron bulkheads, and that it was perceptible also in other ships of the Royal Navy electrically lighted on the two-wire system.

My impression is that the improved dynamos now made have much less of magnetic leakage than those made prior to 1886, but we still want information as to their disturbing magnetic effect at such distances as have to be considered in connection with the compass question.

(4) To ascertain that there is no perceptible compass disturbance, or if there is any to test its amount, the compass should be observed while the current through the dynamo is started and stopped, either by starting and stopping the dynamo itself or by making and breaking the circuit of the field magnets. This should always be done before the electric light installation is taken over from the contractors. It is best and most easily done when the ship is in dock or lying steadily at anchor. On no account ought it to be delayed in a new ship till she goes out for compass adjustment. A determination of the amounts of the disturbance, if any, for all courses of the ship can be made by the aid of my deflector without moving the ship. But a sufficient practical test may be made by first observing the effect of starting and stopping the current on the compass as it stands; then adjusting a small magnet placed on or supported a little above the glass of the bowl, to deflect the compass about 45 degrees, first on one side and then on the other side of its undisturbed position, and in each case observing the effect of starting and stopping the electric current. This effect ought not to be as much as 2 degrees in any of the three cases.—(London Electrician, May 31, 1889.)

The two-wire system has always been required in United States ships, and this, coupled with the facts that a very high insulation is now insisted upon, that a ground detector, shown in Fig. 5, page 251, which will indicate a leak on either pole, is installed, and that the present location of the dynamo room is favorable to compasses, indicate that the compass-disturbing elements of electric-lighting plants have not been overlooked.

LIGHTING PLANTS FOR SHORE STATIONS.

It is now a well-conceded fact that search-lights are very important adjuncts in defending a fort or outpost from surprises and night attacks. Under ordinary circumstances the installation of the necessary plant for these lights does not present any serious difficulties. Recently, however, a plant for detached forts, where fresh water is scarce and very difficult to obtain during siege operations, has been brought out by Messrs. Sautter, Lemonnier & Co., already referred to in this article, which deserves attention. It consists of a compound-wound duplex dynamo of 50 to 70 volts, 100 amperes, and 350 revolutions, directly connected to a single-cylinder vertical engine. There is an upright boiler, condenser, injector, etc. The condenser is cooled by means of air forced through it by a fan ; the latter is driven by means of a belt from a pulley on the end of the dynamo shaft. The horse-power developed is 12, and the actual loss of water per hour is 24 litres. The projector, of the Mangin type, is 90 centimetres in diameter; it is mounted on trucks, so that it may be wheeled about. The outfit comprises all of the accessories and spare articles necessary for the operation, care, and maintenance of the plant for some time, the cost being $6,755.

DYNAMOTOR OR DIRECT CURRENT CONVERTER.

It is probable that the direct current converter will be exceedingly useful at navy-yards and other similar Government stations, for converting a high-pressure current, such as may be received from an arc-light circuit, to a low-pressure current, for use with incandescent lamps. Recently a converter of this kind has been invented by Mr. Jas. Swinburne,* which produces a low-pressure current of constant potential, regardless of load or potential of the primary circuit, the latter within certain limits. As this machine is perfectly portable, it may be utilized for lighting ships at navy-yards, which are under repairs, or for other reasons can not have steam up. They may also be utilized for lighting hospitals and other buildings too remote from the central station of navy-yards for economical distribution on the three-wire system.

The Edison Company, in this country, has also constructed a direct current converter, which is said to have an efficiency of 80 per cent., and to be equal in every way to the Swinburne converter referred to.

---

* Central Station Electric Lighting, Killingworth Hedges, London.

IX.

THE DEVELOPMENT OF THE RESOURCES OF THE UNITED STATES FOR THE PRODUCTION OF WAR MATERIAL.

By Ensign J. B. Bernadou, U. S. Navy

The development of our Navy on a modern basis, a steadfastly advocated and long discussed measure of reform, had its actual beginning in 1882, when Congress authorized the construction of four ships of war of modern type. These vessels were to be unarmored cruisers, armed with high-powered guns, and built wholly of mild steel. While there was reasonable assurance at the time of passage of the act that the necessary supply of structural material could be obtained in the United States, yet it was generally admitted that the broader requirements of armament and protection were quite beyond the capabilities of any domestic plant, and that the practical technical knowledge necessary for the development of certain special classes of apparatus and material did not exist in the country. In the subsequent work of rehabilitation these anticipations were fully realized. The first armor plates and heavy gun forgings were procured from England; electric search lights were not to be had of domestic make, and were purchased in France; the earlier supplies of powder for our heavier guns came from Germany.

Six years have elapsed since the time when the efforts to make modern naval construction a living industry among us first assumed a definite shape. At present, in 1889, besides the unarmored ships above mentioned, there are ten others completed or approaching completion, two of which are being built upon the Pacific coast. Of armored vessels, in addition to the five monitors, there are two battle-ships building, while the construction of three other armored vessels has been authorized. Since March, 1887, no purchases of armor and gun steel have been made abroad, and there is now an assurance of a home supply of all of the various articles required.

It is the purpose of this article to trace briefly the course of development of the resources of the United States for the production of war material; to show how manufacturers, stimulated by the provisions of liberal contracts, were enabled to meet the national demands, and to indicate the precautions taken by the Government to secure uniform excellence of supplies. For purposes of convenience the various lines of independent development will be separately considered, and comparative methods will be resorted to, when practicable, to indicate advances made.

STRUCTURAL MATERIAL.

At the time that the appropriation was made for the first ships of the new Navy, to produce the material for a steel war ship was virtually to create a new industry in this country. There was no assurance of a supply of heavy steel castings, and no plant existed that was capable of making the steel forgings that would be required. That the lighter plates and shapes would be forthcoming was to be expected, in view of the large steel plant existing at the time, which had been developed to meet special needs, and which, in 1884, possessed an annual capacity of yield of over 3,000,000 tons. The following table, compiled from the Directory of the Iron and Steel Works of the United States, gives certain particulars in relation to our steel-producing industry, and will serve to illustrate this:

TABLE I.

Year.	Bessemer.		Open hearth.		Crucible.		Clapp-Griffith.	
	Number of works	Total annual capacity in tons.	Number of works.	Total annual capacity in tons.	Number of works	Total annual capacity in tons.	Number of works.	Total annual capacity in tons.
1882	15	2, 150, 000	27	400, 000	35	105, 000	....	....
1884	21	2, 490, 000	35	550, 000	41	115, 000	....	....
1887 ...	35	4, 750, 000	50	815, 000	41	112, 000	8	225, 000

The problem before the Government, therefore, was first to induce manufacturers, in the face of rigid provisions as to high and uniform quality of material, to start out in a new line, undertaking work that, in view of their lack of experience, might involve them in pecuniary loss; second, to induce them to put their machinery in condition to furnish the new varieties of plates, shapes and forms that would be required.

The acts of 1882–'83, appropriating for the first four ships of the new navy, contained the proviso that "such vessels should be constructed of mild steel of domestic manufacture, having as near as may be a tensile strength of not less than 60,000 pounds to the square inch, with a ductility in 8 inches of not less than 25 per cent." To the Naval Advisory Board was assigned the task of formulating and establishing in accordance with these requirements a series of tests for the material of the various grades; also, that of obtaining exact data upon the various steel plants of the country, and of ascertaining the ability of the proprietors to perform the work that the Government required. The report of the Board, prepared from the records by Assistant Naval Constructor Richard Gatewood, U. S. Navy, and appended to the report of the Secretary of the Navy for the year 1885, gives in full detail the history of the Government development up to that date of the use of mild steel as a ship-building material.

With a view of ascertaining the capabilities of individual domestic plants, the Board, in March, 1883, sent out a circular letter to prominent steel manufacturers, giving dimensions of certain plates, shapes, and bars, such as were assumed as typical of the needs of the immediate future. Answers indicative of a willingness to furnish these in whole or in part were received from nine firms; the dimensions, directly related to the capacity of the rolls, alone seemed to attract attention; the requirement of quality, a factor upon which the value of the supply would be altogether dependent, appeared for the time to have been overlooked.

The schedule of requirements as finally agreed upon by the Board was next submitted to both manufacturers and builders. When coupled with the understanding that all tests should be conducted by naval inspectors of steel who were to be commissioned officers of the Navy, the severity of the requirements became apparent. The report of the Board says: "While most of the steel manufacturers showed a willingness to furnish the material demanded, the ship-builders expressed strong doubts as to the necessary certainty of manufacture and fears of excessive cost."

The prospect of initial difficulties in meeting the high test requirements led to a further discussion of the test schedule, and finally, with the approval of the Secretary of the Navy, certain modifications were adopted. In place of the original limits of 60,000 pounds tensile strength per square inch of cross-section and 25 per cent. elongation in 8 inches as an average of four specimens, an average of 60,000 pounds and 23 per cent. elongation and a minimum limit of 58,000 pounds and 21 per cent. elongation for individual specimens were decided upon as the conditions of acceptance of ship's plates and shapes. The original requirements of 25 per cent. ductility and tensile strength of from 57,000 to 63,000 pounds for boiler plates were adhered to. A further modification, providing for the inspection of metal by heats and not by arbitrarily chosen lots, was subsequently made; still later it was stipulated that all specimens were to be taken from the finished material as produced by heats and not from plates or bars rolled from arbitrarily chosen ingots of a heat. In September, 1883, the regular work of inspection of the steel for the new cruisers began. As had been predicted, the inexperience of the manufacturers in the work of producing large amounts of metal uniform in quality to within narrow limits led to numerous delays, due either to extreme carefulness in methods of procedure or else to the failure of metal furnished. In consequence arose numerous causes of dissatisfaction and disappointment, culminating in the development of a strong opposition to the rigid system of inspection carried out at the steel works by the naval officers. In this connection the Report says:

> In consequence of the delays above mentioned, complaints were made by the contractor that on account of the severity and method of the tests, and consequent slow delivery of material, idle men and tools and empty slips were subjecting him to great additional expense. For a time determined efforts were made to break down the system of tests on the score of impracticability and expense, and it is to be regretted that these objections should have been urged as the cause of delays really due to tardiness and inexperience in manufacture.

That these difficulties were practically overcome at a comparatively early date the report of the Secretary of the Navy for the year 1884 bears witness, as follows:

> The Naval Advisory Board in the course of its duties has inspected and tested about 8,000 tons of mild steel for the new vessels. It has been shown that our steelmakers can readily furnish this excellent material in large quantities, and its high quality has been assured by the tests adopted.

The system established in 1883 has been carried on with but slight modification up to the present time. In 1886 the Advisory Board gave place to the Steel Board, differing from the former in its character of permanency and in that its single and definite function was the inspection of steel for the hulls and machinery of Government ships. In view of increased experience the work of inspection has been carried on by this latter body in a manner even more rigid than that previously obtaining.

Having outlined the measures adopted by the Government to induce manufacturers to furnish a supply of suitable material, let us next consider the improvements that have been made in the last few years in the manufacture of steel for naval uses, and inquire into the effects of the establishment and maintenance of a rigid system of Government tests upon the steel and ship-building industries of the country. These may be grouped under the following headings:

1. Production of large homogeneous forgings (A) and castings (B) of sizes hitherto unobtainable, and increased facilities for the manufacture of plates, shapes (C), and corrugated furnaces (D).
2. Increase in test requirements, and improvement in the quality of steel.
3. Effect of recent Government work and system of inspection in bringing about a general improvement in the quality of steel.
4. Reduction in the price of steel furnished to the Government.

1.—PRODUCTION OF LARGE HOMOGENEOUS FORGINGS, ETC.

A. Forgings.—The failure of the attempt to provide the first of the new ships with steel shaftings of domestic manufacture, and the subsequent long existing doubts as to certainty of supply have given the subject of shafting a marked prominence. The history of the development of this forging may therefore be taken as typical of advances made.

In the report of the Secretary of the Navy for the year 1885 is stated the following:

> The contracts (for the *Dolphin*, *Atlanta*, *Boston*, and *Chicago*) had provided that the vessels should be provided with steel shafts. The first of these, placed in the *Dolphin*, broke upon her trial trip. It had been previously condemned by the Advisory Board

upon the tests made under their direction, and had been put in, nevertheless, upon the responsibility of the contractor. At his suggestion a modification of the contracts and specifications was made by which iron was substituted for steel in the shafts of the four boats

The above will serve as an illustration of the difficulties with which the beginners of the new navy had to contend. We next find that the sub-contracts for the steel shafts of the three ships following were awarded to the foreign firms, Krupp and Whitworth. The manufacture of the shaft for the gunboat *Petrel*, however, for which ship the contract was awarded at about the same time, was undertaken by the Duquesne Steel Company of Pittsburgh, and the forging submitted by this firm having passed the requirements of Government inspection, was delivered to the builders in March, 1888. The steel of which it was made was supplied by the Cambria Iron Works.

The following table, giving certain particulars in relation to the crank-shafts of our recently built ships, will serve to illustrate improvements effected. These forgings for the later vessels have been furnished by the Bethlehem and Midvale companies, reference to whose plant will be made under the headings of ordnance and armor.

TABLE II.

Name of ship.	Particulars of crank-shafts.	Where manufactured.	Diameter of shaft journals.
			Inches.
Dolphin	Wrought iron	Morgan Iron Works, New York.	13
Boston	Wrought iron; steel pins	do	16
Atlanta	Wrought iron; steel pins	do	16
Chicago	Forged steel, with wrought-iron cranks and steel pins.	do	15
Charleston	Steel, forged in one piece; 2-throw; axially drilled.	Krupp	12¾
Baltimore	Steel, forged in one piece; 3-throw; axially drilled.	Whitworth	15
Yorktown	Steel, forged in one piece; 3-throw; axially drilled.	do	9
Vesuvius	Steel, forged in one piece; 4-throw	do	7
Petrel	Steel, 2-throw; forged solid; axially drilled	Duquesne Forge Company. Steel from Cambria Works.	9
Newark	Steel, built up forging; 3-throw; axially drilled.	Bethlehem	13
Philadelphia	Steel, built up forging (forged on mandril), 3-throw.	do	14½
San Francisco	Steel, in three sections (forged on mandril), 3-throw.	do	14¼
Concord	Steel, built up; 3-throw; axially drilled	Forged at Midvale; machined at West Point Foundry.	9
Bennington	do	do	9
Monadnock	Steel, sectional, forged solid; axially drilled	Forged at Midvale; machined at Vulcan Iron Works, Chicago, Ill.	9
Maine	Steel, in three sections; forged solid; axially drilled.	Bethlehem	11

B. Castings.—At the time of the construction of the first ships but little had been accomplished in the United States towards the manufacture and employment of large steel castings. Their uses were limited, and their successful production remained a matter of doubt. In the *Dolphin, Atlanta, Boston, and Chicago* only a few of the smaller of the moving parts of the machinery were made of cast-steel. The stems and stern posts of these ships were forgings made from scrap or from bloom, it not being possible at the time of their fabrication to produce suitable steel castings in their stead. In all later vessels, however, cast-steel stem and stern posts have been required by specification, and these are now successfully furnished. The greater cheapness, the shorter time required for making, the capability of casting more nearly to the finished shape, the greater lightness for the same strength, together with the possibility of casting in a form better suited for riveting, have all tended to hasten the change, which has become possible only through very recent advances in the steel-casting industry, and which the Government has been largely instrumental in bringing about.

The high quality of metal now employed is shown in the specifications, the latest of which call for a tensile strength of at least 60,000 pounds per square inch of cross-section, with an elongation of at least 15 per cent. in 8 inches for all castings for the moving parts of the machinery, and the same tensile strength and an elongation of at least 10 per cent. in 8 inches for all other castings. In addition to the above are the percussive tests for the large masses, and for all a rigid surface inspection for pitting, sponginess, and other kindred defects. A phosphorus limit of .06 per cent. is now required. Open-hearth steel is to be the material for the castings of the *Maine* and *Texas*. The specifications for the coast-defense vessel call also for open-hearth steel.

In the following table will be found the weights and the places of fabrication of the cast-steel stems and stern posts of the larger of our recently-built ships.

TABLE III.—*Table of castings.*

Ship.	Stem.		Stern-posts.	
	Weight.*	Where cast.	Weight.*	Where cast.
Charleston	11, 470	Pacific Rolling Mills, San Francisco, Cal.	11, 130	Union Iron Works, San Francisco, Cal.
Baltimore..	12, 770	Standard Steel Casting Company, Thurlow, Pa.	10, 600	Standard Steel Casting Company, Thurlow, Pa.
Newark..........	16, 590	......do	13, 370	Do.
Philadelphia	12, 450	......do	10, 700	Do.
San Francisco ..	11, 510	Pacific Rolling Mills, San Francisco.	14, 590	Union Iron Works, San Francisco, Cal.

* Castings as shipped to builders.

C. Increased facilities for the manufacture of plates and shapes.—Steel hull and boiler plates have been obtainable from the year 1881. Protective deck plates were supplied in time for their utilization in the first of the new cruisers. The trouble experienced in their manufacture was due to initial inability to provide the requisite character of steel rather than to lack of an adequate rolling plant. The difficulties that were encountered in the beginning in the production of the special varieties of shapes required in hull construction are now practically overcome. Troubles yet arise and delays ensue on account of the absence of a series of Government standard sections for angles, bulb-beams, etc.; also on account of the sections sometimes being decided upon without special reference to those that the mills are ready to make, thus necessitating the turning of new rolls. The production of a new shape, moreover, is liable to be accompanied in any case by delay, inasmuch as the best sections to which to turn the rolls for the production of the same depends to a great extent upon the results of a practical trial.

All of the sizes and sections that have been demanded by the Government have been produced. The bulb angles that take the place of double-flanged beams in the more recent ships are being satisfactorily supplied; a 10-inch Z-bar (flanges, 3-inch) has been rolled, in response to demand, at the Phœnix Works, and passed the Government inspection.

Aside from the quality of the metal, the greatest improvements that have been recently effected in plate-rolling relate to the increase in size of the rolls employed and the consequent capability of production of larger plates. Four years ago the largest rolls in the country were 100 inches long, capable of rolling a plate which, when finished at the shears, would be about 92 inches wide. About three years ago, at the Otis Rolling Mill at Cleveland, Ohio, and at the Parks' Mill at Pittsburgh, were put in rolls 115 inches long; and two years ago the Homestead Works started with rolls 119 inches long, capable of turning out a finished plate 114 inches wide. At present the Homestead rolls (Carnegie) are the largest in the country, but the Otis Company at Cleveland, Ohio, are putting in 123-inch rolls, which will thus give them again the advantage in point of size.

Similar improvements have also been effected in relation to shapes; and the rolls have been increased in size as the shapes have been increased. In April of this year a 24-inch I-beam was rolled at the Homestead Works. A 20-inch beam was the largest ever rolled before that time.

D. Corrugated furnaces.—Among the special forms of recent origin may be mentioned corrugated furnaces, the fabrication of which has been but recently begun in the United States. Their exclusive manufacture is now carried on at the Continental Iron Works at Greenpoint, Brooklyn, N. Y. This establishment has furnished the supply for all the new vessels except the *Chicago*, *Boston*, *Atlanta*, *Dolphin*, and *Charleston*. Among the requirements for the steel for those of the *Monadnock*, under the contract of October, 1888, were a tensile strength of from 50,000 to 58,000 pounds, and an elongation of 26 per cent. The phosphorus limit was set at .03 per cent. The time for the final deliveries was fixed at six months.

2. INCREASE IN TEST REQUIREMENTS AND IMPROVEMENT IN QUALITY OF STEEL.

If the test requirements that have been issued from time to time for the information of contractors and the guidance of inspecting officers be taken up in order, and the separate specifications for each class of material be placed side be side and compared, the great improvements that have recently been effected in the manufacture of steel for Government uses will be made apparent. While the examination of the results of series of heats, with averages of tensile strength and elongation, will show what individual manufacturers have been able to do at given times, the comparison of the test requirements will show in the most concise way what the Government has learned in regard to the general ability of manufacturers to produce higher grades of metal. Inasmuch as the requirements have gradually increased in severity, it follows that improvements in the quality of steel have been continually effected.

The following table is made up of equivalent portions of instructions issued to inspectors at the dates given, omitting bending, quenching, and kindred tests, and including new requirements as they have appeared:

TABLE IV.

Kind of material.	A. 1883-'84.	B. 1887-'88.	C. 1888-'89.	D. 1889-'90.
	Tests for steel for Chicago, Boston, Atlanta, and Dolphin.	*Tests of steel for Charleston, Baltimore, Yorktown, Petrel, and Vesuvius.*	*Tests of steel for Newark, Philadelphia, San Francisco, Concord, and Bennington.*	*Tests for steel for coast-defense vessel.*
Hull plates and shapes.	Test to be made on lots of plates. The average of four test pieces (taken from two plates, one piece from each being cut in the direction of the rolls and the other at right angles thereto) to show an average tensile strength of at least 60,000 pounds per square inch of original cross-section and a final elongation in 8 inches of not less than 23 per cent. If any single piece shows a tensile strength of less than 58,000 pounds or an elongation less than 21 per cent., the plate to be rejected. NOTE.—In October, 1883, a change from tests by lots to tests by heats with test pieces cut from a plate or bar rolled from an ingot or else from the finished material.	For all classes of material except boiler-plate a set of tests both from ingot and from finished material, by heats. (*a*) *Ingot tests.*—The average of four test pieces from a plate rolled from ingot, to be a tensile strength of at least 60,000 pounds per square inch, with an elongation in 8 inches of 25 per cent. No single piece to fall below 58,000 with an elongation of 21 per cent. (*b*) *Test from finished material.*—Four test pieces, each from a different plate or shape of same heat. Each piece to show a tensile strength of at least 60,000 pounds per square inch, and an elongation in 8 inches of at least 25 per cent. If two specimens fail to show that, the heat to be rejected.	Tests to be made by heats on *finished material.* Four test pieces, each from a different object, to show a tensile strength of at least 60,000 pounds per square inch of cross-section and an elongation in 8 inches of at least 25 per cent. If but one of such pieces falls below 60,000 pounds, but not below 58,000 pounds, or below 25 per cent. but not below 23 per cent. elongation, and the average of the four pieces shows a tensile strength of 60,000 pounds and an elongation above 25 per cent., the heat to be accepted. But if two pieces fall below 60,000 pounds and an elongation of 25 per cent., the heat to be rejected.	Plates and shapes to be of steel made by the open-hearth process and not to show more than .06 per cent. of phosphorus. Tests to be made by heats. Four test pieces to show a tensile strength of at least 60,000 pounds per square inch of cross-section and an elongation in 8 inches of at least 25 per cent. If but one of such pieces fall below 60,000 pounds but not below 58,000 pounds, or below 25 per cent., but not below 23 per cent. elongation, and the average of the four pieces shows a tensile strength above 60,000 pounds and an elongation above 25 per cent., the heat to be accepted. But if two pieces fall below 60,000 pounds and an elongation of 25 per cent., the heat to be rejected.

Protective-deck and main-deck plates.			(1) Between 60,000 and 70,000 pounds per square inch with an elongation of from 25 per cent. to 23 per cent. (2) Between 70,000 and 80,000 pounds per square inch with an elongation of from 23 per cent. to 19 per cent. (3) Between 80,000 and 90,000 pounds per square inch with an elongation of from 19 to 12 per cent. One of the above to be selected by the steelmaker before beginning work and afterwards adhered to.	Of open-hearth steel, not to show above .06 per cent. phosphorus. Four test pieces cut, each, if practicable, from a different plate of the same heat. Such pieces to show a tensile strength of at least 80,000 pounds and an elongation in 2 inches of at least 18 per cent.
Rivets......	Besides bending, flattening tests, etc., the provision that the rivet is not to shear under a strain of less than 50,000 pounds to the inch.	(*a*) *Hull.*—Besides bending, flattening tests, etc., sample bars to show a tensile strength of between 50,000 and 55,000 pounds per square inch, and an elongation in 8 inches of at least 30 per cent. (*b*) Boiler rivets that are to be driven by power to have the same tensile strength and elongation as the plates into which they are driven.	(*a*) *Ship rivets.*—The bars from which the rivets are made to show for four specimens a tensile strength of from 50,000 to 55,000 pounds per square inch and an elongation of not less than 30 per cent. If one specimen fall below 30 per cent., but not below 28 per cent., and the lot average 30 per cent., the lot to be accepted. Each ton from same heat or blow to constitute a lot. (*b*) *Boiler.*—Not to show more than .05 per cent. phosphorus. Rivets to be driven by power to possess a tensile strength of from 60,000 to 65,000 pounds per square inch of cross-section and an elongation of not less than 26 per cent. in 8 inches. For rivets to be driven by hand, same tests as those for hull.	(*a*) *Hull.*—Of open-hearth or Clapp-Griffith steel and not to show more than .05 per cent. of phosphorus. The specimens cut from two bars to show a tensile strength of from 60,000 to 55,000 pounds per square inch of cross-section and an elongation in 8 inches of not less than 29 per cent. Two specimens to be taken from ends of bars; if one fall below 29 per cent and not below 28 per cent., and the two average 29, the lot to be accepted. (*b*) *Boiler.*—Of open-hearth or Clapp-Griffith steel and not to show more than .03 per cent., phosphorus. The rivets for longitudinal seams to have a tensile strength of from 58,000 to 67,000 pounds with an elongation of not less than 26 per cent.; for all others, from 50,000 to 58,000 pounds with an elongation of not less than 30 per cent.

TABLE IV—Continued.

Kind of material.	A. 1883–'84.	B. 1887–'88.	C. 1888–'89.	D. 1889–'90.
	Tests for steel for Chicago, Boston, Atlanta, and Dolphin.	*Tests of steel for Charleston, Baltimore, Yorktown, Petrel, and Vesuvius.*	*Tests of steel for Newark, Philadelphia, San Francisco, Concord, and Bennington.*	*Tests for steel for coast-defense vessel.*
Boiler plates	Each plate to be subjected to the same tests as ship plates. As additional requirements the ductility in 8 inches must not be less than 25 per cent. and the ultimate tensile strength not less than 57,000 pounds and not more than 63,000, with an average of at least 60,000 pounds.	Two test pieces from each plate, one in direction of rolls and the other at right angles thereto. For former piece an elongation of not less than 25 per cent. with a tensile strength of between 57,000 and 63,000 pounds per square inch. For the latter, an elongation of not less than 21 per cent. and a tensile strength of between 57,000 and 63,000 pounds per square inch. For flange and furnace plates, an elongation in 8 inches of not less than 29 per cent. with a tensile strength of between 55,000 and 50 000 pounds per square inch.	Not to show more than .05 per cent. phosphorus. (*a*) For boiler plates the elongation in 8 inches to be not less than 20 per cent., and tensile strength between 58,000 and 67,000 pounds per square inch of cross-section. (*b*) For furnace and flange plates, the elongation to be not less than 26 per cent., and the ultimate strength to be not less than 50,000 nor more than 58,000 pounds per square inch of cross-section.	Steel to be made by the open-hearth process. Not to show more than .03 per cent. of phosphorus. *A. Shell plates.*—Transverse specimens to show a tensile strength of between 58,000 and 67,000 pounds, with an elongation of at least 22 per cent. Longitudinal specimens must show a tensile strength of between 58,000 and 67,000 pounds, with an elongation of at least 25 per cent. The elastic limit must be at least 32,000 pounds. (*b*) *Furnace and flange plates.*—Test pieces must show a tensile strength of between 50,000 and 53,000 pounds, with an elongation of 26 per cent. either longitudinally or transversely.

Forgings (steel shafts)		Four test pieces 4 inches long and one-fourth inch sectional area to be taken from end uppermost in ingot, two at circumference of finished diameter, and two at one-half radius from centre. The average ultimate tensile strength to be between 58,240 and 67,200 pounds per square inch, and no piece below 56,000. The elongation of no piece at outer radius to be less than 20 per cent. and that of no piece at inner less than 16 per cent.	Each length of rough-forged shaft to have a piece cut from it at the end that was uppermost in the ingot. Four test pieces 2 inches long and one-fourth inch in sectional area to be taken therefrom; 2 at circumference of finished diameter and 2 at one-half radius. Pieces to be cut either at right angles to axis or to shaft radius. The average ultimate tensile strength of the four pieces to be between 58,000 and 67,000 pounds per square inch. The elongation of no piece at outer radius to be less than 24 per cent., and of no piece at inner to be less than 20 per cent. in 2 inches.	To be made of open-hearth steel. Not to show more than .06 per cent. of phosphorus. A piece to be cut from each end of each length of forged shaft. From the piece removed from the end uppermost in the ingot four test pieces to be taken, two at the circumference of the finished diameter and two at half radius from the centre. The other two specimens to be taken at one-half radius from the centre of the other piece. The average tensile strength of the six pieces to be between 58,000 and 67, 000 pounds. Not more than one piece to fall below 58,000, but not below 56,000; nor more than one above 67,000, but not above 70,000. The elongation of no piece to be less than 24 per cent.
Forgings, engine and miscellaneous.			The average of four test pieces to be not less than 65,000 pounds per square inch, with an elongation of 20 per cent, and no one piece below 62,000 with elongation of 18 per cent.	To be made by the open-hearth process and not show more than .06 per cent. of phosphorus. The average of four test pieces to be between 58,000 and 67,000 pounds. No single piece to fall below 56,000 nor above 70,000 pounds. Each piece to show an elongation of at least 24 per cent.
Castings....		Tensile strength to be between 60,000 and 70,000 pounds per square inch, with elongation in 8 inches of at least 10 per cent.	Tensile strength to be at least 60,000 pounds of cross-section. Elongation in 8 inches to be at least 10 per cent.	Steel either open-hearth or crucible. Not to show more than .06 per cent. phosphorus. All castings to be annealed. A tensile strength of at least 60,000 pounds, with an elongation of at least 15 per cent. in 8 inches for all castings for moving parts of machinery, and at least 10 per cent. in 8 inches for other castings.

In the above table the briefness of the earlier requirements as compared with those of later date will first be noticed. Inasmuch as in 1883–'84 there was no assurance of a supply of protective-deck plates, large steel forgings, and heavy steel castings, the conditions for the acceptance of these classes of material were absent from the circulars issued at that time.

The increases that have been called for, both in tensile strength and in the percentage of elongation, are to be noted for every class. The requirements for hull plates for 1887–'88 show a return to conditions that manufacturers, in 1883, had professed themselves unable to meet.

The change in boiler plates from a tensile strength of between 58,000 and 67,000 pounds, with an elongation of 20 per cent. in 8 inches to the same tensile strength with an elongation of 25 per cent., has been quoted as " not a step but a march in advance."

The exaction of a phosphorus limit for each and every grade of material marks a very great advance in the methods of inspection, and gives an additional assurance of the quality of the metal supplied. In the specifications of 1883–'84 no definite phosphorus limit for any class of material seems to have been called for. In 1888–'89 a limit of .05 per cent. is found established for boiler plates and rivets, while in 1889–'90 a definite limit of from .03 to .06 is set for every grade. It is now customary for the Government inspectors themselves to make analyses of the material furnished by the steel makers.

The policy of the Navy Department of allowing greater latitude to manufacturers, providing that existing disputed requirements be taken as a lower limit of quality, is well shown in the case of protective-deck plates. The original conditions of 60,000 pounds tensile strength, with an elongation of 25 per cent., were complained of as being unduly severe, and doubts were expressed as to whether the requisite grade of metal could be procured. As a compromise the Government submitted a series of conditions, and gave manufacturers the privilege of choosing any specified set. In the latest requirements the Government has again returned to the stipulation of a definite tensile strength and percentage of elongation, but the final figures are more difficult to obtain than those that were originally disputed.

Finally, attention is called to the requirements in column " D," wherein open-hearth steel is specified as the metal to be employed in the manufacture of hull plates, boiler plates, protective-deck plates, and large forgings. For rivets a choice is permitted between open-hearth and Clapp-Griffith steel; for castings, between open-hearth* and crucible steel. The preference of the Department for open-hearth steel is shown in the specifications issued in the years 1888 and 1889.

---

* The specifications for the hull and machinery of the Maine, issued on May 4, 1888, and on July 24, 1888, respectively, are the first to contain definite mention of the kind of steel to be employed for the various classes of material. The words "*ordinary open hearth*" are therein employed. Beginning with the specifications for the hulls of the monitor *Terror* and class, issued January 5, 1889, all specifications contain the words "*steel by the open-hearth process*," thus allowing the employment of basic open-hearth

3. EFFECT OF GOVERNMENT REQUIREMENTS IN BRINGING ABOUT A GENERAL IMPROVEMENT IN THE QUALITY OF STEEL.

In estimating the effect of recent Government work upon the general steel-making industries of the country, it must be borne in mind that the amount of steel used in the construction of naval vessels between the years 1883 and 1889 has been extremely small in comparison to that produced and consumed in the country at large during the same period. To illustrate this, if the tonnage of all the new steel ships built and now building be added together, a total of some 57,000 tons will be obtained, which may be taken as a rough though considerably exaggerated estimate of the actual amount of metal employed. The annual capacity of the steel works of the United States—Bessemer, Open-Hearth, Clapp-Griffith, and Crucible—for the year 1887 alone, is given in the Iron and Steel Directory of that date as 5,902,000 tons. (See Table I.) If one-half of this be taken as the actual production (an under estimate) there will be had a tonnage of 2,951,000. Of this latter amount 57,000 tons, or the whole amount of steel used in the Navy, would be less than 2 per cent.; whence it may be assumed that the consumption for naval purposes during the period of six years has not been more than a fraction of 1 per cent. of the corresponding general annual production.

It should also be remembered, in the consideration of the results accomplished, that large numbers of our steel-making firms have made no reply to the national demands, and that all the material used by the Government has been produced by a relatively small number of establishments.

In answer to inquiries made of private ship-builders as to the effect upon the steel industries of the recent development of very high grades of metal by the Government, it is acknowledged that the capacity of the plants engaged in the work is improved, and the ability to produce high grades of steel increased. It is claimed, however, that the special runs of metal used for Government work are generally handled by gangs of especially trained men, and that the Government tests have not changed the commercial requirements.

On the other hand it is recognized that at those establishments where Government material is produced the private inspection of the higher grades of steel is now carried on in a manner more nearly in accordance with Government methods than those previously obtaining; and it is acknowledged that to the good results of the Government system are to be ascribed the constantly increasing improvements and elaborations in private methods.

---

steel. In the recent specifications for the hulls and machinery of cruisers 7, 8, 9, 10, and 11, issued May 24, 1889, in addition to the phosphorus limit is a sulphur limit of .04 per cent. for all classes of material except castings.

While there is no positive assurance that the time has yet arrived, yet it is safe to assume that the requirements of steel for bridge, boiler, and engine work will soon call for a grade of metal equal to that now used by the Government. No opposition is as bitter and determined as that which is engendered by efforts to avoid the expenditure of large sums of money, and the development of a demand for high grades of steel from conditions where lower grades are now accepted, must necessarily be slow.

What the Navy Department can claim is that it has shown to contractors and consumers of the United States what high and excellent grades of steel can be produced in our own country, and that, by calling the attention of the nation to those establishments where have been found the skill, ability, and inclination sufficient to meet the severe requirements, it has pointed out where the best metal is to be obtained.

4. Reduction in the price of steel furnished to the government.

The reduction in cost of material naturally follows as a result of increased manufacturing capabilities. An additional proof of improvements recently effected is to be found in the fact that while the quality of the steel has increased the price has fallen. By means of the following table, which gives in fractional parts of dollars the cost per pound of plates, shapes, etc., both to the Government and to private builders, an estimate may be made of recent advances.

Table V.*

Name of ship.	Plates.	Shapes.	Rivets.	Castings (hull).	Shafting.
Dolphin Boston Atlanta Chicago	.05	.035-.04	.045	....	....
Newark	.04	.04	.045	.135-.165	.28
Yorktown	.04	.04	.045	.135-.165	.25† .28‡
Philadelphia	.04	.04	.045	.135-.165	.28
Maine	.0334	.0334	.0414	.16	....
Texas	.0324	.0384	.0384	.155	....
Baltimore	....	....	....	....	.25† .28‡
Vesuvius	....	....	....	....	.29‡

† Delivered on the wharf at Liverpool. ‡ Delivered in Philadelphia, including freight and duty.

The prices for steel forgings have a varied range. In recent bids for the steel shafting of the *Monadnock* the figures ran from 40 to 26 cents per pound, the contract being awarded at the latter rate to the Vulcan Iron Works, of Chicago, Ill. The forgings for this shafting were made at Midvale and machined in Chicago. (For dimensions see Table II.) The lighter forgings for the boilers and machinery of this vessel, which are to be furnished by the Midvale Works, average in cost from 16 to 28 cents per pound.

---

* Prices, except for shaftings of Yorktown, Baltimore, and Vesuvius, are for domestic material.

ORDNANCE MATERIAL AND ARMOR.

The need of guns being more pressing in the beginning than that of armor, the subject of ordnance was the first to receive the attention of the Navy Department. The work of designing modern rifles was begun in 1881, and the first proposals for material were issued in that year. The steel for the 6-inch calibre determined upon was satisfactorily supplied on demand by the Midvale Company; that for the 8-inch guns was purchased in England, it being impossible to obtain in this country at the time the requisite steel forgings. Subsequent orders for steel for the 10-inch guns of the *Miantonomoh* were also placed abroad.

Dissatisfied with a make-shift policy that left the Government dependent for its war material upon the products of foreign industry, Congress, in 1883, determined to inaugurate a change. By its authority was then convened the board subsequently known as the Gun Foundry Board, composed of officers of the Army and Navy, and of which Rear-Admiral Edward Simpson, U. S. Navy, was president. This body had for its purpose the consideration of the question of how to establish in the United States in the most economical and the most advisable manner a complete gun-producing plant.

After a thorough examination of methods of fabrication and of the systems of distribution of work between Government and private firms that were found to obtain in the leading foreign countries, the board made an elaborate report, embodying in the final résumé of its labors the following recommendations:

> I. That the Government should establish in its own territory a plant for the fabrication of cannon, and should contract with private parties to such amounts as would enable them to supply from the private industries of the country the forged and tempered material.
>
> II. That two gun factories should be established; one for the Army at Watervliet Arsenal, West Troy, N. Y., and one for the Navy at the Washington Navy-Yard, Washington, D. C.

While the board stated that the question of armor had not been referred to it for investigation, yet it alluded to the fact that the erection of a plant to produce steel gun forgings would go far towards reducing the outlay requisite in order to provide the full means of producing armor.

The direct recommendation of the use of steel for armor was subsequently made by the Select Committee on Ordnance and War Ships and by the Fortification Board, in 1886.

The Government policy being outlined and a choice of material made, it next remained to induce private firms to undertake the share of the work that had been allotted to them. The great initial outlay necessitated, and the doubts as to whether the efforts to rebuild the Navy iwould be continuous, resulted in a hesitancy on the part of the latter to make a beginning, and a period of inactivity was the result.

The Act of Congress of August 3, 1886, authorizing the completion of five double-turreted monitors and the construction of two armored vessels, made possible the immediate guaranty of a large order to any firm that would undertake the erection of the necessary armor plant. There was thus thrown directly into the hands of the Navy Department the possibility of developing the defenses of the nation, an opportunity that had been eagerly watched for by this branch of the service.

The policy of the Navy Department is stated in the report of the Secretary for the year 1888, as follows:

> As a first step in this direction all purchases of armor and gun steel abroad were discontinued. Contracts were pending in March, 1885, for armor and gun steel purchased in England, amounting to $227,365.29. The final payments upon those contracts made subsequent to that date amounted to about $100,000; no further purchases of either armor or gun steel have been made abroad since March, 1885.
>
> As a second step, the wants of the Department for armor and gun steel were allowed to accumulate until contracts of some magnitude could be offered to the competition of domestic manufacturers, one condition of the bidding to be the erection of a plant in this country adequate to the manufacture of both armor and gun steel up to the highest standard of European requirements.
>
> This was deemed an experiment by the Department at the time, and was accompanied with great individual efforts towards enlisting the steel manufacturers in the undertaking, but resulted successfully, and upon the 1st day of June, 1887, contracts were entered into with the Bethlehem Iron Company, of Bethlehem, Pa., one of the largest and most enterprising of American steel manufactories, under which the United States was guarantied that within two and one-half years from the date of the contract this country would have within its borders a plant equal to and probably the superior of any in the world for the production of armor and the forgings for high-powered guns.

As an illustration of the national importance of the results thus obtained by the Navy Department, it may be mentioned that the War Department, in January, 1889 (but four months after the act of September, 1888, authorizing the construction of heavy modern guns for coast defense), was enabled to place a contract with the Bethlehem Company for the supply of forgings for 8-inch, 10-inch, and 12-inch breech-loading high-powered rifles. The act of September, 1888, also provided the additional sum of $700,000 for the erection of the necessary buildings and the procuring of the requisite tools, etc., for the army gun factory at the Watervliet arsenal, for heavy ordnance, thus carrying out the original recommendations of the Gun Foundry Board.

In October, 1886, the Washington navy-yard was set aside for the manufacture of ordnance and for the establishment of the naval gun factory. The funds for the work were supplied by the act of Congress of August 3, 1886, appropriating $1,000,000 for the armament of certain vessels and the erection of the factory plant, the greater part of which was applied to the latter use, and that of March, 1889, making available the sum of $625,000 for the completion of the work, sufficient progress having been made by the latter date to allow an exact estimate of the remaining expenditures necessitated.

Having outlined the process of development of plant, the results obtained are next to be considered. These may be grouped under the following headings:

1. Transition from a state of dependence upon foreign to that of reliance upon home supplies.
2. Manufacture of armor and gun steel for the Government by private firms.
3. Capabilities of assembling and finishing guns.
4. Improvements in quality of steel.
5. Diminution in cost of steel.

1. TRANSITION FROM A STATE OF DEPENDENCE UPON FOREIGN TO THAT OF RELIANCE UPON HOME SUPPLIES.

Tables VI and VII give the particulars of the contracts for armor and gun forgings made by the Government subsequent to 1882–'83 and show when the last foreign purchases were made.

TABLE VI.—*Armor.*

Year.	Purpose.	Kind.	Tons.	Price per ton.	Manufacturer.	Delivery.
1882–'83	For testing armor-piercing projectiles.	A small order of a few tons for experimental purposes.				
1883	Experimental, for Clark's deflecting turret.	Small order			Schneider, leCreusot, France.	
1883	Turrets of *Miantonomoh.*	Compound.	215	*‡$532.40	Messrs. John Brown & Co., and Cammell & Co., Sheffield, England.	Turret plates in six months; those of pilot-house in ten months.
Since March, 1885, no purchase of armor made abroad.						
June, 1887†	Armor for four monitors and for *Maine* and *Texas.*	Steel	6,700	‡538.70	Bethlehem Iron Company, Bethlehem, Pa.	Delivery to begin two and one-half years from date of contract.

From June, 1887, a supply of armor of domestic manufacture guarantied under Bethlehem contract.
* Delivered in New York.
† Date of contract.
‡ Average cost.

TABLE VII.—*Gun forgings.*

Year.	VI-inch.	VIII-inch.	X-inch.	XII-inch.
1883–'84	Midvale	Cammell & Co., Sheffield, England, and Sir Joseph Whitworth, Manchester, England.	Cammell & Co., Sheffield, England, and Sir Joseph Whitworth, Manchester, England.	
1884–'85	Do			
Since March, 1885, no purchases of gun steel have been made abroad.				
1885–'86	Midvale	Hoops at Midvale	Hoops at Midvale	
1886–'87	Do	Do	Hoops at Midvale	
1887–'88	Midvale and Bethlehem	Bethlehem	Bethlehem and hoops at Midvale.	Bethlehem.

From May, 1887, a supply of heavy forgings of domestic make guarantied under the Bethlehem contract.

It will be noticed that the orders for armor placed abroad have all been very small. The immediate need of guns for the new ships led, however, to more extensive contracts, and a number of sets of the forgings for the tubes for the 8-inch calibre, as well as a few sets of the same for the 10-inch calibre, were supplied by foreign establishments. The following extract from the report of the Chief of the Bureau of Ordnance for the year 1885, in relation to the armament of the new vessels, indicates the conditions of production of ordnance material at that time:

> The forgings for the 8-inch guns * * * have just arrived from Sir Joseph Whitworth, of Manchester, England. * * * The steel is more than a year over due from the English maker, and the delay in its receipt furnishes an excellent argument for encouraging the establishment of a heavy gun-forging plant in the United States.

Complaints of tardiness in delivery of material contracted for abroad are frequent in the official reports of this period, and aided greatly in creating a popular sentiment in favor of the speedy establishment of a home plant.

2. FIRMS MANUFACTURING ARMOR AND GUN STEEL FOR THE GOVERNMENT.

The Midvale Steel Company, of Nicetown, Pa., were pioneers in the work of making steel guns in the United States. In June, 1882, a contract was made with this firm for the steel for two 6-inch B. L. guns, and they have since satisfactorily filled numerous orders. In 1885 they commenced the fabrication of the chase hoops for the 8-inch and 10-inch calibres. They have not yet produced for the Navy, however, the forgings for the tubes and jackets for any size above the 6-inch, and up to the time of the Bethlehem contract the latter had been purchased abroad. In compliance with the terms of its contract of May and June, 1887, with the Navy Department, for about 6,700 tons of armor and 1,200 tons of gun steel, the Bethlehem Iron Company, of Bethlehem, Pa., has been most actively engaged in erecting its plant for the production of gun forgings and armor plates. The forging plant is now in working order, and with it have been forged 8-inch tubes and jackets, and the heavy shafting for the *Philadelphia*, *San Francisco*, and *Newark*. The armor plant is now in process of erection and will doubtless be ready for work within the contract time. When completed (within the year) the Bethlehem will be one of the finest establishments of its kind in the world. Its plant will include Whitworth's liquid compression for the production of steel ingots, hydraulic forging presses capable of forging the parts of guns up to 16-inch calibre, one of the heaviest hammers in the world for forging armor plates, and tools of the most approved type for machining armor plates and rough-boring and rough-turning gun-forgings.

Steel plates for gun shields are now readily obtainable, being furnished of excellent grade by the Homestead Steel Works, the Linden Steel Company, and Park Bros. & Co.

The steel castings that are now used whenever practicable as component parts of carriages are satisfactorily supplied by the Standard Steel Casting Company and by the Midvale Steel Works.

In relation to the development of the production and employment of the latter, the report of the Chief of the Bureau of Ordnance, 1888, contains the following:

> Orders have been placed for thirty-two sets of steel castings for the 6-inch central-pivot carriages of the new ships. Some of the steel makers still find difficulty in obtaining the necessary ductility in these castings, but on the whole they are reasonably successful, and thus far thirteen sets have passed the ballistic tests. * * * The Bureau, however, expects that in time steel top carriages and steel slides may each be cast in one piece.

Within the last year slides for the 6-inch gun have been satisfactorily cast in one piece and are now furnished.

3. CAPABILITIES OF ASSEMBLING AND FINISHING GUNS.

The first of the 6-inch high-powered guns were assembled at the Washington navy-yard and at the private plants of the West Point and the South Boston Companies. In October, 1886, as before mentioned, the Washington yard was practically turned over to the Bureau of Ordnance for the establishment of a naval gun factory. Since that date, aided by the appropriations above referred to, the work of development has been pushed rapidly ahead. The plant for calibres up to 8-inch, and which is capable of doing 10-inch work, is now in working order; the 10 to 12 inch plant will be complete and in operation by the end of the year; while the tools for the 16-inch are now being manufactured.

The output of the naval gun factory at Washington in finished guns up to June, 1889, has been as follows:

Guns.	Number.	Carriages.
5-inch	2	2
6-inch	30	37
8-inch	4	9
10-inch	3	2

The plant when completed is to be capable of turning out twenty-five 6-inch and twelve 12-inch B. L. R. per year, or the equivalent in other calibres, working eight hours per day, with the carriages, equipments, and all accessories that would belong to the same. In addition the plant is intended to supply the demands for mounts and accessories for the secondary batteries, and to supply the annual waste of ordnance material and stores.

4. IMPROVEMENT IN QUALITY OF STEEL.

The following table for the 6-inch, the only calibre that has yet been constructed wholly of domestic material, will serve to exhibit the improvements effected in the quality of the steel produced by the Midvale Company.

TABLE VIII.*

Part of gun.	Tensile strength.			Elastic limit.			Elongation after fracture.			Reduction of area after fracture.		
	1882–'83. No. 1.	1885. No. 18.	1889. No. 35.	1882–'83. No. 1.	1885. No. 18.	1889. No. 35.	1882–'83. No. 1.	1885. No. 18.	1889. No. 35.	1882–'83. No. 1.	1885. No. 18.	1889. No. 35.
Tube	74,768	84,530	75,290	29,833	42,149	38,027	28.52	23.87	22.70	39.41	46.05	31.66
Jacket...	75,000	88,300	86,920	34,065	44,200	47,109	27.58	22.80	24.75	42.23	38.50	46.05
A hoop ..	102,267	116,700	95,876	44,733	68,700	50,708	18.48	14.92	23.72	26.79	25.90	47.69
A hoop ..	88,465	......	......	39,810	....	....	25.53	....	....	37.41	....	....
A hoop ..	93,733	121,769	104,133	41,235	68,980	52,202	23.71	15.95	18.78	36.72	31.05	35.87
A hoop ..	86,436	....	....	41,030	....	....	29.40	....	....	45.60	....	....
A hoop ..	91,523	108,112	99,787	52,337	63,025	54,240	....	15.20	22.80	....	29.18	42.74
A hoop ..	94,607	....	....	49,553	....	....	18.67	....	....	28.35	....	....
A hoop ..	90,799	107,543	....	41,694	59,854	....	23.30	16.45	....	32.27	32.65	....
A hoop ..	109,881	....	....	44,117	....	....	12.32	....	....	12.31	....	....
B hoop ..	107,314	101,672	106,255	46,297	53,618	57,636	18.17	16.70	19.95	24.19	29.20 A″ in No. 1.	34.33
C hoop ..	93,030	99,608	100,890	33,104	54,932	56,107	16.45	17.42	20.13	21.16	39.36 A′ in No. 1.	46 41
D hoop ..	93,956	103,297	99,227	49,569	53,287	55,937	25.51	16.42	21.48	37.78	29.56 B in No. 1.	43.20
E hoop ..	110,574	102,700	92,827	44,896	55,200	47,788	15.13	17.30	20.45	18.73	33.10	37.21
	102,880	....	....	44,727	....	....	18.90	....	....	26.49	C_1 in No. 1.	
F hoop ..	88,555	119,738	98,038	29,254	62,631	55,937	22.36	18.05	19.12	32.59	35.26 C_2 in No. 1.	41.15
G hoop ..	101,879	103,171	102,393	42,755	61,148	57,723	17.20	17.77	19.52	20.90	36.61 D_1 in No. 1.	39.95
Tr hoop .	82,501	81,191	....	45,701	41,600	....	12.30	12.10	....	22.00	13.32 D_2 in No. 1.	....

* NOTE.—The data guns for Nos. 1 and 18 are taken from Proceedings Naval Institute, 1886—"The Navy 6-inch B. L. R.," by Ensign T. S. Rodgers, U. S. Navy.

In addition to the above it might also be shown that the percentage of rejections has been reduced.

5. DIMINUTION IN COST OF MATERIAL.

The report of the Secretary of the Navy for 1887 contains the following in relation to the Bethlehem contract:

> * * * The contracts for armor and gun steel are made at prices within 25 per cent. of the European price for the similar material, not greater than the difference in labor between the two countries, notwithstanding the heavy outlay for plant (estimated at $2,500,000) necessary to be made to undertake the contract.

The prices agreed upon to be paid by the Government for steel armor and appurtenances was averaged at $538.70 per ton, or 24 cents per pound, as follows:

TABLE IX.*

Kind of material.	Estimated number of tons.	Price per ton.	Price per pound.	Price per class.
Side armor for *Puritan*	734. 7	$510. 00	$0. 22, 8	$374, 697. 00
Side armor for *Amphitrite* and class	1, 066. 8	510. 00	. 22, 8	544, 068. 00
Turrets and pilot-houses for four monitors	835. 8	575. 00	. 25, 7	480, 585. 00
Smoke-pipes and ventilators for four monitors	266. 3	575. 00	. 25, 7	153, 122. 50
Armor for breastworks for two armored vessels	680. 0	575. 00	. 25, 7	391, 000. 00
Armor for turrets, conning towers, and ammunition tubes for two armored vessels	485. 0	575. 00	. 25, 7	278, 875. 00
Part of side armor for two armored vessels	364. 0	500. 00	. 22, 3	182, 000. 00
Do	468. 0	525. 00	. 23, 4	245, 700. 00
Do	468. 0	600. 00	. 26, 9	280, 800. 00
Rolled plates, protective deck armor, and gun shields.	1, 135. 0	490. 00	. 21, 9	556, 150. 00
Turret and side armor bolts and other accessories.	181. 0	650. 00	. 29, 0	117, 650. 00
Small armor bolts, steel	6. 0	650. 00	. 29, 0	3, 900. 00
Tubing and washers, wrought-iron	12. 0	180. 00	. 08, 0	2, 160. 00
Total	6, 702. 6	†538. 70	†0. 24, 0	3, 610, 707. 50

* Compare with Table VI.

† Average price.

Table X gives a comparison of prices and terms as stipulated in the recent contracts concluded by the Navy and the Army with the Bethlehem establishment and by the Navy with the Midvale.

TABLE X.—*Gun forgings.*

[Except when otherwise noted, prices are for material rough-bored and turned, and oil-tempered.]

Kind of forging.	U. S. Navy. Early Midvale and foreign contracts.	Price (cents per pound).	U. S. Navy. Conditions of Midvale contract of May, 1887.	Price (cents per pound).	U. S. Navy. Conditions of Bethlehem contract of May–June, 1887.	Price (cents per pound).	U. S. Army. Conditions of Bethlehem contract of December, 1887.	
VI-inch.	1883–4 Midvale.							
Tubes and jackets	(Tubes, plugs, and jackets) ..	*18	One set of 6-inch forgings to be delivered in 60 days and not less than one set every 21 days thereafter; the whole contract to be completed within 9 months, subject to conditions relating to rejected forgings.	32	The express stipulation of the erection by the Bethlehem Company of a gun and armor producing plant adequate to the manufacture of the forgings required under this contract (including armor). The plant to be estab-	28	....	....
Hoops	....	32		29.5		28	....	....
VIII-inch.	Purchased abroad, 1884–5.							
Tubes and jackets.......	Cammell (tubes, jackets, and B-rings).	†27	....	....		30	Sets of VIII-in. forgings. A. First set in 12–15 months. B. First set in 15–18 months. C. First set in 18 months. Subsequent deliveries at the rate of 18 sets in 12 months.	27⅓ 25⅓ 24
	Whitworth (tubes, jackets, and B-rings).	†19.6						
	Whitworth (tubes, jackets, and B-rings, including freight).	20.5						
Hoops	....	†16	....	....		28		
	Midvale, 1885	36–40						
X-inch.	Purchased abroad, 1884–5.							
Tubes and jackets.......	Cammell (tubes, jackets, and B-rings).	†27	....	....		32	A. First set in 24-27 months. B. First set in 27-30 months. C. First set in 30-33 months.	30½ 29½ 28½

	Whitworth (tubes, jackets, and B-rings).	†19.6			lished and fully equipped within two and one-half years from the time of agreement, and the delivery of the material contracted for to begin at the end of that time.		Sets of X-in. forgings.	D. First set in 33-36 months.	27½
	Whitworth (tubes, jackets, and B-rings, including freight).	20.5						E. First set in 36 months.	26½
Hoops		†16	(Small order of 6 chase hoops.)	55		32		Subsequent deliveries at the rate of 12 sets in 12 months.	
XII-inch.								A. First set in 27-30 months.	30½
								B. First set in 30-33 months.	29½
Tubes and jackets						34	Sets of XII-in. forgings.	C. First set in 33-36 months.	28½
								D. First set in 36 months.	27½
								Subsequent deliveries at the rate of 6 sets per 12 months.	
Hoops						32			
							For all the above a penalty of .02 cents per pound for each month overdue.		

---

* Not bored, turned, or oil-tempered.

† Purchased abroad duty free, exclusive of freight.

In the foregoing pages attention has been given entirely to the advances made in the production of steel for hulls, machinery, armor, and guns. It remains to cite briefly the conditions of the development of those special classes of apparatus and material the technical knowledge for the successful production of which did not a few years ago exist among us. The more important of these may be taken up and discussed briefly in turn.

SECONDARY BATTERIES.

Until very recently, revolving cannon and rapid-fire guns were only to be obtained by purchase abroad. Desirous of providing for their domestic manufacture, the Navy Department, in 1887, while refusing to purchase the foreign guns, guarantied to the Hotchkiss Company, of Paris, France, on condition that they would erect within the United States the necessary plant for the fabrication of both guns and ammunition, the following order:

6-pounders	30
3-pounders	22
1-pounders	10
37^{mm} revolving cannon	32

Also a supply of ammunition for the whole.

The offer having been accepted, the work was begun in 1887. The contract is now being executed, and it is expected that it will be completed by January, 1890. After considerable initial difficulties the steel has been satisfactorily produced by the Midvale Company. The guns are now building at the works of the Pratt and Whitney Company, of Hartford, Conn., and the ammunition is being furnished by the Winchester Arms Company, of New Haven, Conn.

In view of the present tendency towards the establishment on large vessels of primary batteries, composed of rapid-fire guns, the value of the possession of the Pratt and Whitney and Winchester plants has been increased, and their significance greatly enhanced.

PROJECTILES.

Cast-iron shell are produced with facility. The supply is now manufactured at the Washington navy-yard, but could be supplemented by the productions of many private establishments.

The efforts to obtain cast-steel shell were long unsuccessful, the first samples being all rejected on account of imperfections in castings. Recent specimens, however, submitted by I. G. Johnson & Co., of Spuyten Duyvel, N. Y., the Standard Steel Company, of Thurlow, Pa., and the Pittsburgh Steel Casting Company, of Pittsburgh, Pa., have passed inspection, and the certainty of the necessary supply is now guarantied.

The Bureau of Ordnance has been trying to produce chrome steel of domestic make suitable for armor-piercing projectiles. Samples have been submitted by the Chrome Steel Company, of Brooklyn, N. Y., and by the Midvale Company. These, as far as have been tried, have not proved altogether satisfactory; but further experiments are in progress, and with a view to developing their manufacture the Bureau has advertised for a large number of finished armor-piercing projectiles for 6-inch, 8-inch, and 10-inch guns, and it is hoped that their production, up to the requirements of the French standard, will be soon undertaken.

The Simond's Rolling Mill, of Fitchburg, Mass., has made satisfactory samples of projectiles rolled from carbon and chrome steel, requiring only to be bored and turned at the point, thus assuring the existence of another source of supply of projectiles, when demanded; but as yet this company has not been actively engaged in the manufacture of the same.

POWDER.

The original supply of brown powder for the U. S. S. *Atlanta* was purchased from the Rhenish-Westphalian Powder Company, of Germany, in 1884, it not being possible at that time to produce a suitable grade in the United States. The want was met, however, by Messrs. Dupont & Co., of Wilmington, Del., to whose efforts the successful development of slow-burning powder in this country is due. Satisfactory samples for the 6-inch were submitted in 1885, and since that time a supply has always been procurable. The same firm also developed a powder for the 8-inch in 1887, and samples of a powder for the 10-inch have been since submitted for trial.

The supply of high explosives for the Navy is manufactured at the Torpedo Station at Newport, R. I. The encouragement of private manufacturers whose works are located back from the Atlantic has been recommended, as such increased production would be of great service in time of war.

TORPEDOES.

The Hotchkiss Ordnance Company has now commenced the manufacture of the Howell Torpedo, for which it has purchased the rights, and the manufacturing establishment has been located at Providence, R. I. In August, 1888, the Navy Department decided to order thirty of these torpedoes and executed a contract with the company to that effect, reserving the right to extend the order to fifty, under certain conditions. These being the first manufactured and the order given a small one, the prices paid were in the nature of an inducement to the establishment of a manufacturing plant, and were therefore relatively high.

ILLUMINATING PLANTS AND SEARCH-LIGHTS.

The great advantages in healthfulness, safety, accessibility, economy, and efficiency that are to be derived from the employment of an incandescent plant on shipboard for purposes of interior illumination were first made manifest by the Bureau of Navigation, of the Navy Department, in September, 1883, in the case of the U. S. S. *Trenton*, the first man-of-war of any nation that was equipped with a complete electric illuminating plant. There was also established by this Bureau in 1883 the office of the inspector of electric lighting, whose duties were the determination of the character of and the general inspection of the condition and quality of the plants supplied to naval vessels, and to whose efforts the present excellence of our naval installations is chiefly due.

It has been shown in General Information Series, No. VII, that the search light used in the Navy is the Sautter-Lemonnier hand lamp with the Mangin projector; also that the hand lamps, but not the projectors, have been manufactured in the United States. Arrangements have recently been made, however, by the Navy Department, for securing both hand lamps and projectors of American manufacture. The following table, giving the sources of the supply of the plants for recently built vessels, will serve to indicate advances made:

TABLE XI.

Name of ship.	Incandescent plant.	Search-light plant—where manufactured.		
		Lamp and projector.	Engine.	Dynamo.
Trenton	Edison Company	Sautter, Lemonnier & Co., Paris, France.	Brotherhood & Co., London, England.	Gramme. Sautter, Lemonnier & Co., Paris, France.
Atlanta	U. S. Electric Lighting Company.	....do	....do	Do.
Boston	Brush Company	....do	....do	Do.
Chicago	Edison Company	....do	....do	Do.
Yorktown	Edison United Company.	Thomson-Houston Company.	Armington & Sims	Thomson-Houston
Baltimore	....do	....do	Domestic	Domestic.
Charleston	....do	....do	....do	Do.

In the preceding portion of this article an effort has been made to outline the course of the domestic development of the several individual implements of naval warfare. It remains to show how far the endeavors of the Navy Department to enlist the aid and co-operation of the manufacturing industries of the several sections of the country in the work of reconstruction have been successful, and to indicate the distribution of the various operations involved between Government and private plants. For these purposes Table XII, giving from the beginning the nature of work performed, the names of the principal firms undertaking the same, and the location of their manufacturing establishments has been compiled. Mention is therein made of certain classes of work not heretofore especially dwelt upon in the text, on account of there not having existed at any time a serious deficiency in the plant for the production of the same. Attention is called to the recent undertakings of Southern yards and shops; also to the important part that the establishments of the Pacific coast have played in advances recently effected. It is to be hoped that the time is near at hand when an independent plant for the production of all classes of material for steel-ship construction will he found upon our Western coast.

TABLE XII.

DOMESTIC SUPPLY OF MATERIAL FOR WAR PURPOSES.

UNARMORED VESSELS.

Hulls.	Where built.	Year.	Name of vessel.	Machinery.
Delaware River Ship-Building Company (John Roach).	Chester, Pa	1883	Dolphin	Morgan Iron Works, New York (John Roach).
Do	do	1883	Boston	Do.
Do	do	1883	Atlanta	Do.
Do	do	1883	Chicago	Do.
The William Cramp & Sons Ship and Engine Building Company.	Philadelphia, Pa	1886	Baltimore	The William Cramp & Sons Ship and Engine Building Company.
Do	do	1887	Newark	Do.
Do	do	1887	Philadelphia	Do.
Do	do	1887	Yorktown	Do.
Do	do	1887	Vesuvius	Do.
N. F. Palmer, jr., & Co. (Delaware River Ship-Building Company.)	Chester, Pa	1887	Concord	N. F. Palmer, jr., & Co. (Quintard Iron Works), Brooklyn, N. Y.
Do	do	1887	Bennington	Do.
Columbian Iron Works and Dry Dock Company.	Baltimore, Md	1886	Petrel	Columbian Iron Works and Dry Dock Company.
Union Iron Works.	San Francisco, Cal	1886	Charleston	Union Iron Works.
Do	do	1887	San Francisco	Do.
Herreshoff Manufacturing Company.	Bristol, R. I	1888	Torpedo-boat	Herreshoff Manufacturing Company.

ARMORED VESSELS.

Hulls.	Where built.	Year.	Name of vessel.	Machinery.
U. S. navy-yard	Brooklyn, N. Y	1888	Maine	N. F. Palmer, jr., & Co. (Quintard Iron Works, Brooklyn, N. Y.).
Delaware River Ship-Building Company (John Roach).	Chester, Pa	*1874	Miantonomoh	Morgan Iron Works, New York (John Roach).
Do.	do	*1875	Puritan	Do.
The William Cramp & Sons Ship and Engine Building Company.	Philadelphia, Pa	*1874	Terror	The William Cramp & Sons Ship and Engine Building Company.
The Harlan & Hollingsworth Company.	Wilmington, Del	*1874	Amphitrite	The Harlan & Hollingsworth Company.
U. S. navy-yard	Norfolk, Va.	1888	Texas	The Richmond Locomotive Works, Richmond, Va.
Secor & Co	Vallejo, Cal	*1874	Monadnock	U. S. navy-yard, Mare Island, Cal.
Union Iron Works	San Francisco, Cal	1887	Coast-defense vessel	Union Iron Works, San Francisco, Cal.

* Keel-laid, but not yet completed.

STRUCTURAL MATERIAL.

[N. B.—This list is made out *exclusive* of foreign firms.]

EARLY SOURCES OF SUPPLY FOR *Dolphin*, *Atlanta*, *Boston*, and *Chicago*:

- Ship plates:
  - Chester Rolling Mills, Thurlow, Pa.
  - Norway Steel and Iron Company, South Boston, Mass.
  - Black Diamond Steel Works. Park Bros. & Co., Pittsburgh, Pa.
- Boiler plates:
  - Chester Rolling Mills, Chester, Pa.
  - Norway Steel and Iron Company, South Boston, Mass.
- Shapes:
  - Phœnix Iron Company, Phœnixville, Pa.
  - Cambria Iron Company, Johnstown, Pa. (blooms for shapes).
- Rivets:
  - Pittsburgh Steel Casting Company, Pittsburgh, Pa. (steel for do.).
  - Jones & Laughlin, Pittsburgh, Pa.
  - Combination Steel and Iron Works, Lamokin, Pa.
- Forgings (stem and stern posts):
  - Nashua Iron and Steel Company, Nashua, N. H.
- Forgings (machinery):
  - Nashua Iron and Steel Company, Nashua, N. H.
  - Morgan Iron Works, New York.

PRESENT SOURCES OF SUPPLY, LATER VESSELS:

- Ship plates:
  - Carnegie, Phipps & Co., Homestead Steel Works, Pittsburgh, Pa.
  - Linden Steel Company, Pittsburgh, Pa.
  - Spang Steel and Iron Company, Pittsburgh, Pa.
  - Black Diamond Steel Works, Park Bros. & Co., Pittsburgh, Pa
  - Chester Rolling Mills, Chester, Pa.
- Boiler plates:
  - Spang Steel and Iron Company, Pittsburgh, Pa.
  - Carnegie, Phipps & Co., Homestead Steel Works, Pittsburgh, Pa.
  - Linden Steel Company, Pittsburgh, Pa.
  - Black Diamond Steel Works, Park Bros. & Co., Pittsburgh, Pa
  - Chester Rolling Mills, Chester, Pa.
- Protective deck plates:
  - Linden Steel Company, Pittsburgh, Pa.
  - Carnegie, Phipps & Co., Homestead Steel Works, Pittsburgh, Pa
- Thin plates for bulkheads, etc.:
  - Spang Steel and Iron Company, Pittsburgh, Pa.
  - Sligo Rolling Mills, Phillips, Nimmick & Co., Pittsburgh, Pa.
  - Singer, Nimmick & Co., Pittsburgh, Pa.
  - Soho Iron Mills, Moorehead, McCleane & Co., Pittsburgh, Pa.
- Shapes:
  - Carnegie, Phipps & Co., at (A) Union Iron Works, Pittsburgh (all large shapes); (B) Homestead Steel Works (some small shapes).
  - Phœnix Iron Company, Phœnixville, Pa.
  - Pacific Rolling Mills, San Francisco, Cal.
  - Cambria Iron Company, Johnstown, Pa. (blooms for do).
  - Pennsylvania Steel Company, Steelton, Pa. (blooms for do.).
- Rivets:
  - Carnegie, Phipps & Co., Homestead Steel Works, Pittsburgh, Pa.
  - Oliver Steel Company, Pittsburgh, Pa. (formerly Oliver Bros. & Phillips).
  - Hoopes & Townsend, Philadelphia, Pa.
  - Pottsville Iron and Steel Company, Pottsville, Pa. (rods for do.
  - Pacific Rolling Mills, San Francisco, Cal.
- Heavy forgings:
  - Bethlehem Iron Company, Bethlehem, Pa.
  - Midvale Steel Company, Nicetown, Pa.
  - Duquesne Steel Company, Pittsburgh, Pa
- Forgings for machinery, etc.:
  - Linden Steel Company, Pittsburgh, Pa.
  - Cleveland City Forge and Iron Company.
  - Midvale Steel Company, Nicetown, Pa.

PRESENT SOURCES OF SUPPLY, LATER VESSELS—Continued.

Forgings for machinery, etc.—Continued.
- Pacific Rolling Mills, San Francisco, Cal.
- Bethlehem Iron Company, Bethlehem, Pa.
- Bridgeport Forge Company, Bridgeport, Conn.

Castings (stem and stern posts):
- Standard Steel Casting Company, Thurlow, Pa.
- Pacific Rolling Mills, San Francisco, Cal.

Castings (machinery, etc.):
- Standard Steel Casting Company, Thurlow, Pa.
- Solid Steel Casting Company, Alliance, Ohio.
- Midvale Steel Company, Nicetown, Pa.
- Pittsburgh Steel Casting Company, Pittsburgh, Pa.
- Pacific Rolling Mills, San Francisco, Cal.

Boiler stays, tubes, etc.:
- Cambria Iron Works, Johnstown, Pa.
- American Tube and Iron Company.
- Pacific Rolling Mills, San Francisco, Cal. (stays).
- Syracuse Tube Company, Syracuse, N. Y.
- National Tube Company, McKeysport, Pa.
- Tyler Tube Company, Boston Mass.

Corrugated furnaces:
- Continental Iron Works, Green Point, Brooklyn, N. Y.

ARMOR.

Armor plates and accessories (see Table IX):
- Bethlehem Iron Company, Bethlehem, Pa.

Gun shields:
- Linden Steel Company, Pittsburgh, Pa.
- Homestead Steel Works, Pittsburgh, Pa.
- Park Bros. & Co, Black Diamond Steel Works, Pittsburgh, Pa.

GUN FORGINGS.

Navy:
- Midvale Steel Company, Nicetown, Pa.
- Bethlehem Iron Company, Bethlehem, Pa.

Army:
- Midvale Steel Company, Nicetown, Pa.
- Cambria Iron Works, Johnstown, Pa.
- Bethlehem Iron Company, Bethlehem, Pa.

GUNS, ASSEMBLING.

Navy:
- U. S. navy-yard, Washington, D. C.
- South Boston Iron Works, Boston, Mass.
- West Point Foundry, Cold Spring, N. Y.

Army:
- Watervliet Arsenal, West Troy, N. Y.
- Watertown Arsenal, Watertown, Mass.
- West Point Foundry, Cold Spring, N. Y.
- South Boston Iron Works, Boston, Mass.

RAPID-FIRE AND MACHINE GUNS.

- Pratt & Whitney Company, Hartford, Conn.
- Gatling Gun Company, Hartford Conn.

GUN-CARRIAGES.

- U. S. navy-yard, Washington, D. C.
- Pneumatic Gun Carriage and Power Company (carriages are manufactured at the South Boston Iron Works).

PNEUMATIC DYNAMITE GUNS.

Pneumatic Dynamite Gun Company, New York (guns made by William Cramp & Sons).

PROJECTILES.

U. S. Navy:
  Cast-iron:
    U. S. navy-yard, Washington, D. C.
  Cast-steel:
    I. G. Johnston & Co., Spuyten Duyvil, N. Y.
    Standard Steel Casting Company, Thurlow, Pa.
    Pittsburgh Steel Casting Company.

AMMUNITION FOR RAPID-FIRE AND MACHINE GUNS.

For revolving cannon and R. F. G. of any calibre.
  Winchester Arms Company, New Haven, Conn.
37^{mm}:
  Union Metallic Cartridge Company, Bridgeport, Conn.

TORPEDOES.

Howell:
  Hotchkiss Ordnance Company, Providence, R. I.

EXPLOSIVES.

Gunpowder:
  Dupont Powder Mills, Messrs. du Pont de Némours & Co., Wilmington, Del.
High explosives:
  Torpedo station, Newport, R. I.

In the above brief treatment of an extensive subject it has only been possible to outline the progress that has been made by the comparison of results successively obtained. Enough has been given, however, to emphasize the following important facts: The advance of the United States on the way to independence of all foreign supplies for the production of war material; the provisions for the manufacture of every recognized class of weapon and material within our own borders; the widespread distribution of Government orders; the cordial co-operation and support of the manufacturers of all sections of the country, and the recognition by numerous competitors of the prestige accompanying the participation in supplying the national needs.

That the private industries throughout the country have been so widely stimulated and encouraged is chiefly due to the intelligent and persistent study of the question of developing the domestic resources for the national defense made by the Navy Department and naval officers since 1881.

NOTES

ON

SHIPS, MACHINERY, ORDNANCE, ARMOR, TORPEDOES, TORPEDO-BOATS, AND OTHER SUBJECTS OF PROFESSIONAL INTEREST.

SHIPS.

UNITED STATES.

The naval appropriation bill for the fiscal year ending June 30, 1889, passed during the first session of the Fiftieth Congress, and approved on September 7, 1888, authorized the following new constructions:

VESSELS PROPOSED OR LAID DOWN.

ONE FIRST-CLASS ARMORED CRUISER.

The displacement is to be about 7,500 tons, and the cost, exclusive of armament, is not to exceed $3,500,000. The designs of this vessel are not yet completed.

ONE FIRST-CLASS PROTECTED CRUISER.

This vessel is to be built of steel, of about 5,300 tons displacement, and is to cost not over $1,800,000. This price is exclusive of armament and of any premiums paid for increased speed over 20 knots; these premiums, if the vessel is built by contract, are to be $50,000 for every quarter of a knot above the requirement; for every quarter of a knot that the vessel fails of reaching the contract speed, a penalty of the same amount is to be deducted from the contract price. The designs are not yet completed.

TWO SECOND-CLASS PROTECTED CRUISERS. (Nos. 7 and 8.)

The displacement is to be about 3,000 tons, and the cost, exclusive of armament and speed premiums, over 19 knots, is not to exceed $1,100,000 for each. The speed premiums and penalties are the same in character and amount as above.

Proposals for these cruisers were invited on June 14, 1889, to be opened on August 22, 1889. They are of four classes: The first for hull and machinery of Navy Department design; the second, hull and machinery of contractor's design; the third, hull of Department, and machinery of contractor's design; and fourth, hull of contractor's, and machinery of Department design.

A proposal not to be for more than one vessel complete, but a bidder may propose separately for one or both of the vessels, and under one or more of the four classes. The vessels are to be completed in two years from date of contract.

The designs of the Department call for an armament disposed as follows: One 6-inch B. L. mounted on central pivot-carriage, on topgallant-forecastle, and one 4-inch R. F. G.* on each side of poop; four 4-inch R. F. G. are in each broadside on spar-deck; the forward and after guns sponsoned for bow, and for stern fire. Of the six torpedo-tubes the bow and stern tubes are fixed, and the four broadside tubes train. The auxiliary battery comprises two 6-pdr., two 3-pdr. R. F. G., two 37-millimetre R. C.,† and two Gatlings.

The contract speed is 19 knots, and the estimated I. H. P. 10,000. Twin screws are to be worked by vertical, four-cylinder, triple-expansion engines; the diameters of the cylinders are 36, 53, 57, and 57 inches; the length of stroke is 33 inches. Steam is to be furnished by four double-ended and two single-ended boilers.

---

* Rapid-fire guns.

† Revolving cannon.

The complete protective deck, 2.5 inches on slope, has a double knuckle, and will have patent fuel stowed over inclined parts; above it at the water-line a coffer-dam, filled with woodite or other cellulose material, runs along ship's side.

A steel conning tower is placed on topgallant-forecastle.

The principal dimensions are: Length, 300 feet; beam, 42 feet; and displacement at a mean draught of 18 feet, 3,100 tons. The vessels will have double bottoms; will be rigged as two-masted schooners and have a military top half way up each mast; the rudder is balanced and carries out the lines of the after body of the ship. Bridges connecting the poop and forecastle are run on each side at rail.

THREE SECOND-CLASS PARTIALLY-PROTECTED CRUISERS. (Nos. 9, 10, and 11.)

To be of not over 2,000 tons displacement, and to cost, exclusive of armament and speed premiums, not over $700,000 each. The speed premium to be fixed by the Secretary of the Navy. The vessels to be built of steel.

On May 24, 1889, proposals were invited from bidders to be handed in by August 1, 1889; they are in four classes as in cruisers No. 7 and 8. The vessels to be completed in two years.

The battery is composed of two 6-inch B. L. as bow and stern guns on topgallant forecastle and poop, and eight 4-inch R. F. G. in broadside, the forward guns sponsoned for bow, and the after, for stern fire. The light guns are two 6-pdr. and two 3-pdr. R. F. G., two 37-millimetre R. C., and two Gatlings. The torpedo-tubes are, one in bow and one aft, fixed, and two in each side, training.

The contract speed is 18 knots for four consecutive hours, and the I. H. P. 5,400. Two four-bladed screws are worked by vertical, three-cylinder, triple-expansion engines; the diameters of cylinders are 26.5, 39, and 63 inches; length of stroke 26 inches. Steam is to be supplied by three double-ended, horizontal, return fire-tubular, steel boilers, and two single-ended. The normal coal allowance is fixed at 200 tons, but the bunker capacity is 435 tons.

A complete protective deck has a thickness over vitals of 0.43 inch on slope, and 0.3 inch on flat; forward and aft the average thickness is 0.37 inch. A coffer-dam 15 inches wide, filled with woodite or other cellulose material, runs above the protective deck alongside of fore and aft bulk-heads, its top 4 feet above L. W. L. Athwartship bulkheads are worked from it to ship's side, forming a girdle of water-tight compartments. A conning tower of 2-inch steel is placed on the topgallant-forecastle.

The principal dimensions are: Length, 257 feet; beam, 37 feet, and displacement 2,000 tons, at a mean draught of 14 feet 6 inches. The rig is that of a two-masted schooner, with small sail area. The stem and stern posts are of cast-steel; the rudder is of same type as for Nos. 7 and 8, but is not balanced. A bridge, 4 feet wide, runs athwartships from top of pilot-house to extremities of the forward sponsons. The poop and forecastle will be connected by a bridge, starting from forward in two parts, each 30 inches wide, along the sides of smoke pipes and fire-room hatches, uniting abaft these and continuing as a single bridge 3 feet wide to the poop.

ONE STEEL PRACTICE VESSEL.

This vessel, of 800 tons, is to be built for use at the Naval Academy, at a cost of $260,000.

The same Congress, at its second session, by the act approved March 2, 1889, making appropriations for the year ending June 30, 1890, authorized the following:

ONE ARMORED STEEL MONITOR.

The designs for this coast-defense vessel were prepared at the Navy Department, on suggestions made by the Hon. J. R. Thomas, United States Representative from Illinois and member of the Naval Committee, to the Secretary of the Navy.

The plans are not quite completed; the armament will be composed of one 15-inch pneumatic gun fixed in bow, two 10-inch B. L. in a 10-inch armored turret forward, some smaller guns, and two under-water torpedo-tubes.

The engines, working twin screws, are to develop 7,500 I. H. P., and the cruising speed is to be 17 knots. The vessel will be completely armored, have double sides and bottom, and be fitted with tanks for water-ballast to sink her from cruising to fighting trim.

The principal dimensions are: Length, 325 feet; beam, 55 feet; cruising displacement 3,030 tons at a mean draught of 14 feet 6 inches; the fighting draught is 17 feet 6 inches. The mast is placed forward of the smoke-pipe, thereby getting the maximum efficiency from its military top.

ONE CRUISER OF VESUVIUS TYPE.

The conditions require that the vessel shall not be of less dimensions than the *Vesuvius*, described on page 300 of General Information Series, No. VII; and she is to attain, under similar conditions as to trial, a speed of 21 knots an hour, with an endurance of not less than fifteen days at 10 knots an hour; to be armed with two pneumatic guns of 15-inch calibre, and to be fitted for such other armament as the Secretary of the Navy may prescribe; provided that the contractors (the Pneumatic Dynamite Gun Company) shall guarantee a speed of 20 knots an hour, and that there shall be deducted from the contract price the sum of $10,000 for every quarter of a knot that said vessel fails of reaching the further speed of 21 knots per hour.

The cost is not to exceed $450,000. All of the above is conditional on the efficiency of the *Vesuvius* and her armament being shown by the official trials to be satisfactory to the Secretary of the Navy.

TWO STEEL CRUISERS OR GUN-VESSELS.

They are to have a displacement from 800 to 1,200 tons, and are to cost, exclusive of armament, not more than $700,000 each.

RAM FOR HARBOR DEFENSE.

This vessel is to be of the general type approved by the Naval Advisory Board in their report to the Secretary of the Navy of November 7, 1881, and is to have the highest practicable speed.

The naval appropriation bill approved March 3, 1887, authorized the building of coast and harbor defense vessels, and appropriated toward their construction the sum of $2,000,000.

COAST DEFENSE VESSEL (No. 1).

This vessel was designed at the Department, and the contract for building was given to the Union Iron Works at San Francisco, Cal., in June, 1889. The contract price was $1,628,950. The vessel to be completed in three years.

The vessel is of the monitor type, low free board, built on the bracket system; has a double bottom along entire length and numerous water-tight compartments.

The battery, as designed, is composed of one 16-inch, 110-ton B. L. in forward barbette and one 12-inch, 46-ton in the after one; one 15-inch pneumatic gun in bow; six 4-inch and some 6-pdr. and 3-pdr. R. F. G.

The estimated speed is 16 knots. The two vertical triple-expansion engines are to develop (including air and circulating pumps) an I. H. P. of 5,400 for four consecutive hours; the premiums are $100 for each I. H. P. maintained during the trial above that figure; the penalties, if the power falls below 5,400 are $100 per I. H. P., and if the power maintained during the trial falls below 4,800 the vessel will not be accepted.

The diameters of the cylinders are 27, 41 and 64 inches; the length of stroke is 30 inches.

Steam is to be supplied by two single-ended, horizontal, return fire-tubular boilers, and such tubulous, sectional, or coil boilers as may be determined, all to work at a pressure of 160 pounds.

The armor is of steel and consists of a complete belt, with a maximum thickness of 16 inches, tapering to 8 and 6 inches at ends. The barbettes have 16, and 14-inch armor, and a complete protective deck has a thickness of 3 inches over vitals and 2 inches at ends. The conning tower has armor of 10 inches and the base of smoke-pipe 6 inches.

The principal dimensions are: Length, 250 feet; beam, 59 feet; and displacement 4,000 tons at a mean draught of 14 feet 6 inches.

The bow is ram-shaped. One military mast is placed abaft the smoke-pipe. The complement is to be seventeen officers and one hundred and fifty men.

VESSELS BUILDING.

The contract for the machinery of the *Texas*, p. 297, No. VII, was awarded in May 1889, to the Richmond Locomotive and Machine Works, of Richmond, Va., for $635,500. For particulars of the engines, etc., see Notes on Machinery, page 363 of this number.

The machinery contract for the armored cruiser *Maine* was given to Messrs. N. F. Palmer, jr., & Co., of New York, for $735,000. For description of machinery, see Notes on Machinery, p. 362. The ship is described on p. 298, No. VII.

The monitor *Puritan* is to be completed at the New York yard, to carry a battery of four 12-inch B. L. in two covered barbettes and six 4-inch R. F. G., two on sponsons in the superstructure between the barbettes and four on top, in the four corners. The auxiliary battery comprises two 6-pdr., four 3-pdr. R. F. G., and four 37-millimetre R. C. The barbette armor is 12 inches and the side armor tapers from 14 inches towards the ends. The original number of boilers (ten) is reduced by two and forced draft is to be introduced.

The *Newark*, p. 239, No. VI, and p. 299, No. VII, laid down in June, 1888, the *Philadelphia*, p. 299, No. VII, in April, 1888, will both be launched soon. The *San Francisco*, p. 299, No. VII, was laid down in August, 1888, and will probably be ready for launching this fall. The *Concord* and *Bennington*, p. 300, No. VII, laid down in May, 1888, will be launched with their boilers on board.

VESSELS LAUNCHED.

BALTIMORE.

The first-class protected cruiser of that name was launched on October 6, 1888, at the yard of William Cramp & Sons, Philadelphia.

A full description of this vessel will be found on p. 237, No. VI.

PETREL.

The launch of this vessel took place on October 13, 1888, and she is now ready for steam trials. A description will be found on p. 241, No. VI (as gun-boat No. 2) and on p. 299, No. VII.

STEAM TRIALS.

VESUVIUS.

This cruiser is described on p. 242, No. VI, and on p. 300, No. VII. The weight of machinery is 256.5 tons. At a full-power trial on January 11, 1889, the vessel, displacing 810 tons, was run twice over a measured base 2.5433 knots long. The trial took place in Delaware Bay, near the end of the ebb tide. The first run, with the tide, gave a speed of 22.947 knots; the second, against the tide, 20.346 knots, or a mean speed for the trial of 21.646 knots, 1.646 knots above the contract requirement. The mean boiler pressure was 160 pounds and the mean number of revolutions 271.85; the mean I. H. P. was 4,295 for the main engines and 150, estimated, for the auxiliaries, a total I. H. P. of 4,450. A progressive trial gave, with 340 I. H. P., 125.3 revolutions and a speed of 10.6 knots; with 851 I. H. P., 175.75 revolutions, speed 14.88 knots; with 1.918 I. H. P., 230.6 revolutions, speed 18.94 knots. The coal allowance of 150 tons gives a steaming radius of about 5,800 nautical miles, at a speed of 10 knots.

YORKTOWN.

The *Yorktown* was described on p. 240, No. VI, as Gun-boat No. 1, and her launch is mentioned on p. 300, No. VII. The propelling machinery consists of two horizontal, direct-acting, triple-expansion engines working three-bladed screws of 10 feet 6 inches diameter and 12 feet 6 inches mean pitch. The diameters of the cylinders are 22, 31, and 50 inches; the length of stroke 30 inches. There are four cylindrical, three-furnace boilers, furnishing steam at 160 pounds pressure. The total weight of machinery is 333.75 tons.

On February 13, 1889, the vessel had a four-hour forced-draft trial at sea, the displacement when leaving yard being 1,720 tons, with a draught of 13 feet 4 inches forward and 15 feet 4 inches aft; weights were put on board to represent the battery, etc. During the trial indicator-cards were taken every quarter of an hour. The air pressure in fire-room was 1.5 inches, the mean pressure in boilers 150.5 pounds, and in cylinders, starboard, 57.67–32.82–10.02; port, 55.65–35.56–10.72; vacuum, 24.84 and 25.02; revolutions, 157.98 and 155.94. I. H. P. in cylinders 519.76 + 588.78 + 471,16= 1,579.7 starboard, and 495.41 + 631.89 + 498.28 = 1,625.58 port, or 3,205.58 for both main engines; I. H. P. of air, circulating, and feed pumps and blowers 186.97; total mean I. H. P. 3,392.55; the maximum was 3,705.13. The mean patent log speed was 16.14 knots and the maximum 17.2 knots.

CHARLESTON.

This protected cruiser, described on p. 238, No. VI, and p. 298, No. VII, was launched on July 19, 1888. On May 9, 1889, the vessel made a trip from San Francisco to Santa Barbara, and on the 11th had a short preliminary official trial, which was not concluded on account of the heating of the slides at high piston speeds. During the trial an I. H. P. of 5,564 was developed and the speed of 17.75 knots; the highest speed by patent log was 18.25 knots. The draught of the ship was 17 feet 3 inches forward and 19 feet aft.

ENGLAND.

According to an Admiralty return presented to Parliament on April 4, 1889, the effective navy of Great Britain consisted at the beginning of this year of 62 armored ships (6 of which were waiting for their guns), 29 protected and partially protected, and 282 unprotected craft, including 131 torpedo-boats. Described as obsolete in type and speed were 4 iron-clads and 26 unprotected vessels, the great majority of the latter class being on foreign stations. In 1894, according to the Government programme, the fleet will number 76 armored ships, 88 protected and 336 unprotected vessels, including 147 torpedo-boats.

VESSELS PROPOSED OR LAID DOWN.

The rather weak construction programme of last year has been followed by a well-considered building project spread over a period of four and a half years, and embracing a very large addition to the British fleet of vessels of nearly all classes. The whole number of such vessels is 70, comprising 8 first-class battle-ships and 2 second-class; 9 first-class protected cruisers, 31 second-class, and 18 torpedo vessels.

Of the above number 32 are to be given out to contract during this year at a cost of about £10,000,000 ($48,665,000); the total cost of carrying out the programme is estimated at £21,500,000 ($104,629,750). Of the first class battle-ships, one is to be of the turret type, the others are to have barbettes.

ONE BATTLE-SHIP (TURRET).

In the Parliamentary paper, on page 87, and in Mr. W. H. White's paper, page 97, will be found a complete description, accompanied by plans. The vessel, named the *Hood*, will be built by the Government in the Chatham yard; the armor, compound, is to be furnished by Messrs. Charles Cammel & Co., Cyclops Works, Sheffield.

SEVEN BATTLE-SHIPS (BARBETTE).

With the exception of having barbettes instead of turrets, and some consequent changes due to the difference of weight in the two systems of gun-protection, these are sister ships to the above, and the description will be found under the same references.

One, the *Royal Sovereign*, is to be built at Portsmouth, Cammell & Co. to furnish the armor; two, the *Renown* and *Repulse*, at Pembroke, and the others by contract. Messrs. John Brown & Co., Atlas Steel and Iron Works, Sheffield, are to supply the compound armor, for the *Renown* and *Repulse*.

TWO BATTLE-SHIPS (SECOND CLASS).

These are reproductions of the above on a smaller scale, except in regard to speed and coal endurance. The displacement is 9,000 tons and the estimated I. H. P. 10,000.

One, named the *Centurion*, is to be built at the Portsmouth yard, the other by contract.

NINE FIRST-CLASS PROTECTED CRUISERS.

These vessels are of an enlarged and improved *Mersey* type, and are to carry the same batteries as the *Blake* and *Blenheim*, laid down last year, *i. e.*, two 9.2-inch B. L. as bow and stern guns on upper deck, ten 6-inch B. L. placed in broadside on the two decks, as in the new battle-ship designs, and they will have similar protection, *i. e.*, each gun is to have its own protective turret. The auxiliary battery comprises twelve 6-pdr. R. F. G.; four torpedo tubes are to be fitted.

The estimated measured-mile speed is 20 knots, and the sea speed 18 knots. The vertical triple expansion engines are to develop an I. H. P. of 12,000 under forced and 7,500 with natural draft, and a coal capacity of 850 tons is to give a steaming radius of 10,000 knots at a 10-knot speed.

The protective deck is to be complete, and have a maximum thickness of 5 inches; complete double bottoms and numerous water-tight compartments complete the protection to be given.

The principal dimensions are: Length, 360 feet; greatest beam, 60 feet; displacement, 7,350 tons, at a mean draught of 23 feet 9 inches; this displacement will be increased, and the speed given above, somewhat reduced in some of the vessels by sheathing, to adapt them for particular service on stations where there are no docking facilities.

Three are to be laid down in 1889 and completed in 1892, the *Hawke* at Chatham, the *Edgar* at Devonport, and the *Centaur* at Portsmouth.

TWENTY-NINE SECOND-CLASS PROTECTED CRUISERS.

These vessels represent enlarged and improved *Medeas*. (See p. 306, No. VII.) The battery is composed of two 6-inch B. L. bow and stern guns, six 4.72-inch R. F. G., and nine 6 and 3-pdrs. The torpedo armament numbers four tubes.

In respect to speed, I. H. P., coal capacity and protection, the above will be about the same as the *Medea* class. The principal dimensions are: Length, 300 feet; greatest beam, 43 feet; displacement, 3,400 tons, with a mean draught of 16 feet 6 inches.

A considerable number of the second-class cruisers are to be wood-sheathed and coppered. In these the displacement will be about 200 tons greater, and the speed about a quarter of a knot less.

Two ships of this class, the *Andromache* and *Apollo*, have been laid down at the Chatham yard; the others will be built by contract.

PALLAS—PEARL—PHILOMEL—PHŒBE.

All to be laid down in Government yards this year. The *Pallas* at Portsmouth, *Pearl* at Pembroke, and the others at Devonport; the *Phœbe's* keel was laid in May, 1889. These vessels are second-class protected cruisers of a modified *Medea*, or *Pandora* type, described below.

EIGHTEEN TORPEDO VESSELS.

Sharpshooter type, described on page 303, No. VII. Four are to be laid down in Government yards this year. The *Antelope* at Devonport, and the *Circe*, *Hebe*, and *Leda* at Sheerness.

GOSSAMER—GLEANER.

Sister vessels to the above. They are both building at Sheerness, where their keels were laid in January, 1889.

PANDORA—PELORUS—PERSIAN—PHŒNIX—PSYCHE.

The above names were given to the five protected cruisers building for the Special-service Australasian squadron, according to the agreement stated on page 304, No. VII. The contract for building the hulls of the *Pandora*, *Pelorus*, and *Persian* was awarded to Armstrong, Mitchell & Co., Elswick, and for the machinery to R. W. Hawthorn, Leslie & Co. The *Phœnix* and *Psyche* are building at Clydebank, J. & G. Thomson are the contractors. All the vessels are to be delivered by the builders in such a condition that they will only have to take their coal, ammunition, stores, and crews on board to be ready to go into action. The armament is supplied by the Government.

WHITING—WIZARD.

Torpedo vessels (*Sharpshooters*), building under contract by Armstrong, Mitchell & Co., for the Australasian squadron.

MAYFLOWER.

This name was given to the training brig laid down October, 1888, at Pembroke. She is to be completed at Devonport in 1889. The principal dimensions are: Length, 105 feet; beam, 33 feet 6 inches; mean draught, 13 feet 6 inches at a displacement of 508 tons.

VESSELS LAUNCHED.

VULCAN.

The torpedo transport and depot ship described on page 303, No. VII, was launched at Portsmouth on June 13, 1889. As the keel was laid on the 18th of June, 1888, this shows very rapid work on a 6,620-ton vessel.

BARROSA—BARRACOUTA.

Two third-class protected cruisers, described on page 302, No. VII. They were launched respectively on April 16, and May 16, 1889; the *Barrosa* at Portsmouth and the *Barracouta* at Sheerness.

BEAGLE—BASILISK.

The first was floated out of her dock at Portsmouth on February 28, 1889. The engines for the vessel were built by contract with Rennie, London.

The *Basilisk* was floated at Sheerness on April 6, 1889; her keel was laid last August. The teak sheathing of these vessels is 3.5 inches thick and extends to 2 feet above the load water-line. The protective deck, 1.5 to .75 inches thick, extends only over the magazines and machinery space. The vessels are described on p. 302, No. VII.

LAPWING—RINGDOVE—GOLDFINCH—REDBREAST.

Gun-vessels of 805 tons, described on p. 303, No. VII. The *Lapwing* was launched on March 7 at Devonport, where her keel was laid in May, 1888. The engines were built by the Government at Keyham, in the Devonport yard, as were also those of the *Ringdove*, launched at the same yard on April 30. The launch of the *Goldfinch* took place at Sheerness on May 18, and that of the *Redbreast* at Pembroke on June 12, 1889.

SHARPSHOOTER—SPANKER—SPEEDWELL—SHELDRAKE—SKIPJACK—SALAMANDER—SEAGULL.

A general description of these torpedo vessels was given on p. 303, No. VII. They have topgallant forecastles and high conning towers to enable them to steam into a head sea at good speed. On top of the conning tower an electric search-light is carried. A complete steel protective deck is fitted, and the coal-bunkers are placed outboard of the engines and boilers. Of this class eighteen additional vessels are projected. The *Sharpshooter* was launched on November 30, 1888; the *Spanker* on February 27, 1889; the *Speedwell*, on March 15; the *Sheldrake*, on March 30; *Skipjack*, April 30; and the *Salamander* and *Seagull*, on May 31, 1889.

STEAM TRIALS.

SANSPAREIL.

Sister ship to the *Victoria*, described on p. 111, No. IV; p. 42, No. V (under name of *Renown*), and on p. 247, No. VI. On p. 307, No. VII, the *Victoria's* steam trials are noted.

The engines of both vessels were built by Messrs. Humphrys, Tennant & Co., of Deptford, England. The contract I. H. P. was 12,000 with forced draft, and the estimated speed was 17 knots. The coal allowance of 1,200 tons gives a steaming radius of 7,600 nautical miles at 10 knots.

On September 20, 1888, the *Sanspareil* had a four-hour natural-draft contractor's trial of machinery. The mean boiler pressure was 133.57 pounds; vacuum, 27.5, port and starboard engines; revolutions, 87.37 and 86.86; I. H. P., 4,109.76 + 3,929.66 = 8,039.42. The mean speed by patent log was 16 knots.

Two days after this the four-hour forced-draft trial took place. The vessel was brought down to her mean load draught of 26 feet 9 inches by ballast. The mean air pressure in fire-rooms was 1.9 inches of water; the mean boiler pressure was 130 pounds; vacuum, 26 inches. The hourly data of revolutions and I. H. P. are below:

Hours.	Revolutions.		I. H. P.		
	Starboard.	Port.	Starboard.	Port.	Collective.
First	100.5	100.0	7,177.16	7,126.99	14,304.15
Second	101.4	101.6	7,363.04	7,469.21	14,832.25
Third	101.6	101.6	7,264.94	7,369.43	14,661.37
Fourth	99.8	100.0	7,060.82	7,072.49	14,133.31
Mean	100.8	100.8	7,216.49	7,266.28	14,482.77

The contract horse-power was exceeded by 2,482.77, and that developed in the *Victoria* by 238. The mean speed was 17.75 knots.

TRAFALGAR.

A full description of this vessel is given on p. 204, No. VII. The change of the broadside battery there indicated has been carried out, and there are three 4.72-inch R F. G. in each side. The unarmored side of the upper citadel has received four inches of armor protection against R. F. guns and detonating shell.

On June 26, 1889, the mean of a four-hour run with natural draft gave an I. H. P. of 8,590 (contract 7,500); average number of revolutions, 85; steam pressure in boilers, 133 pounds; vacuum, 27.5 inches.

The speed in eight runs over the measured mile with and against the tide was, respectively 14.87, 16.51, 15.31, 17.10, 15.85, 17.24, and 17.48; mean, 16.213.

MEDEA—MEDUSA.

The twin-screw, vertical, triple-expansion engines of these vessels were built by Messrs Humphrys, Tennant & Co. The diameters of the cylinders are 33.5, 47, and 74 inches; length of stroke, 39 inches. The boilers, four in number, are double-ended cylindrical, and have 24 corrugated furnaces. The ships are described on p. 244, No. VI, and p. 306, No. VII.

The *Medea* had a natural-draft twelve-hour trial on December 10, 1888, being at her designed load draught of 15 feet 3 inches forward and 17 feet 9 inches aft.

With a mean boiler pressure of 140 pounds the mean number of revolutions was 130, the I. H. P. 6,099, and the speed over 17 knots. Two days later a forced-draft trial failed to developed the contract I. H. P. of 9,000, but on December 20 another trial showed a boiler pressure of 149 pounds; vacuum, 26 inches; revolutions, 140, and an I. H. P. of 9,183; but as the screws were of fine pitch the speed fell short of the estimated 20 knots.

The *Medusa*, launched on August 11, 1888, had the twelve-hour natural-draft trial on March 6, 1889. The mean results were: Boiler pressure, 152.5; vacuum, 27.8; revolutions, starboard 129.9, port 130.5; I. H. P., 6,334, and speed, 18 knots.

For the four-hour forced-draft trial on March 13, the air pressure in fire-room was 1.9 inches; pressure in boilers, 149 pounds; vacuum, starboard and port, 26.5 and 26.6; revolutions, 143.6 and 143, and the I. H. P., 9,435.3. The speed was unsatisfactory for the same reason as in the *Medea*.

During a trial in June following, four runs were made over the measured mile at a speed of 19.6 knots, 0.4 knots below the estimated speed.

MAGICIENNE—MARATHON—MELPOMENE.

These vessels are described on p. 244, No. VI, and p. 306, No. VII. The *Magicienne's* natural-draft trial on March 20, 1889, was stopped after the fifth hour on account of the leaking of the feed-pipe. The mean boiler pressure was from 130 to 135 pounds and the speed 17 knots. The best performance was during the fifth hour, with the following data: Revolutions, starboard and port, 126 and 125.9; I. H. P. in cylinders H. P., I. P., and L. P., 890 + 1,048 + 1,063, = 3,001, and 802 + 894 + 1,083 = 2,779, or a total I. H. P. of 5,780.

The forced-draft trial on March 23 was not successful, owing to the smallness of the steam-ports of the cylinders, and consequent back pressure at high piston speeds, it was impossible to work up to the contract horse-power. A speed of 18 knots was made with 7,500 I. H. P. On a trial on April 17 only 8,000 I. H. P. was reached, and on May 7 a third forced-draft trial was unsuccessful. The fourth trial on June 1 had to be stopped at the end of the third hour on account of priming of the boilers. During the three hours the average number of revolutions was 138; the mean I H. P., 4,339 starboard, and 4,441 port engine; collective, 8,780. The mean speed of four runs over the measured mile was 18.85 knots.

On June 15, 1889, the *Magicienne* had another forced-draft trial with the pitch of her screws changed this time from 17 feet 9 inches to 17 feet. All weight were on board and she was at her designed mean load draught of 17 feet 6 inches. For the four hours the steam pressure was 148 pounds; vacuum, starboard and port, 23.28 and 24; revolutions, 144 and 143.2; I. H. P., 4,516 + 4,746 = 9,262. The maximum I. H. P, was 9,607. The estimated speed of 19.75 knots was not reached; the mean of four runs over the measured mile gave 19.126 and the patent log showed 76.6 knots for the four hours.

The *Marathon* had a satisfactory natural-draft trial on May 27, 1889, and made a speed of 17.5 knots. During the forced-draft trial the mean boiler pressure for four hours was 146 pounds; the vacuum, starboard and port, 22.75 and 24.43; revolutions, 142.76 and 145.3; I. H. P., 4,423 and 4,357; total, 8,780 (contract, 9,000); but for the last two hours of trial the I. H. P. was 9,031 and 9,173. The patent-log speed was 18.81 knots. The vessel was at her designed load draught.

The *Melpomene* was launched at Portsmouth on September 20, 1888, and was taken out for a twelve hour natural-draft trial on June 19, 1889, when with a average of 128 revolutious the mean I H. P. of 6,216 was developed, and a mean speed of 17.4 knots was made in several runs over the measured mile.

On June 22, 1889, during the four-hour forced-draft trial, the mean I. H. P. was 9,651, or 651 above the contract figures, while that developed during the last hour of the trial was 9,975. The average speed was 19.75 knots, or just what was estimated; the highest speed reached during the trial was 20 knots.

NYMPHE—DAPHNE.

Sister vessels of the *Buzzard* type, p. 195, No. V, p. 244, No. VI, and p. 306, No. VII. The engines are of the triple-expansion type and drive twin screws. The diameters of the cylinders are 18.5, 29.5, and 43.5 inches; the length of stroke is 2 feet. The estimated I. H. P was 1,400 with natural, and 2,000 under forced draft. Steam is furnished by two cylindrical boilers with three furnaces each. The total weight of machinery is 192 tons and the contract price for it was £15,150 ($73,730)

The natural-draft trial of the *Nymphe* took place on October 29, 1888, the vessel drawing 11 feet forward and 13 feet 4 inches aft, the designed load draught. For the twelve hours the mean boiler pressure was 127 pounds; the average number of revolutions, 149, and the I. H. P., 1,440. The mean speed by patent log was 12.8 knots. The vacuum was rather poor. Coal consumption per I. H. P., 2 pounds.

On November 8, 1888, off Portsmouth, the four-hour forced-draft trial trip was successful. Mean boiler pressure, 135 pounds; revolutions, 161; vacuum, 21 inches; I. H. P., starboard engine 1,013, port 1,063; collective, 2,076. The mean speed was almost 14.5 knots. The coal consumption was large.

The *Daphne* had a natural-draft twelve-hour trial last November. Working at 150 revolutions per minute, the engines averaged 1,463 I. H. P., and the mean speed was 13.6 knots. The four-hour forced-draft trial on the 14th of the month was as satisfactory. With an average of 170 revolutions, the I. H. P. was 2,084, or 84 above the contract requirement. The mean speed was 14.1 knots.

SERPENT—RACCOON.

The natural and forced draft trials of these vessels were given on p. 311, No. VII. For their subsequent performances, see Chapter II, English Naval Manœuvres, pp. 23 to 80.

After thorough repairs and refitting the *Serpent* had a forced-draft trial on November 9, 1888, being at the time at her designed load draught. The results for four hours were: Boiler pressure, 127.4; vacuum for starboard and port engines, 21.4 and 23.2; revolutions, 151.8 and 149.7; I. H. P., 590 + 835 + 806 = 2,231, and 551 + 682 + 787 = 2,020, or a total mean I. H. P. of 4,251; the highest reached was 4,452. As the sea was rough, the speed was only 16.22 knots.

The *Raccoon* had a forced-draft trial on February 20, 1889, off Devonport. The draught of water was 12 feet 7 inches forward and 14 feet 8 inches aft; mean, 13 feet 7.5 inches (designed mean draught, 13 feet 6 inches). For the four hours the mean pressure in boilers was 132 pounds; in cylinders, starboard and port, 45 — 33 — 13.2 and 40.2 — 23.5 — 10.8; vacuum, 21 and 23.5; revolutions, 162 and 156; I. H. P., 644 + 958 + 910 = 2,512 and 554 + 800 + 716 = 2,070, or a total mean I. H. P. of 4,582; the highest reached during the trial was 4,730. The mean speed was 17.6 knots.

MELITA.

A single-screw fourth-class cruiser, built at Malta, and described on p. 197, No. VI, and p. 306, No. VII, obtained last March a speed of 13 knots; rather more than was estimated.

PHEASANT—PARTRIDGE—PEACOCK—PIGEON—PIGMY—PLOVER.

These single-screw gun vessels are described on p. 245, No. VI, and p. 306, No. VII. The engines are triple expansion; diameters of cylinders, 20, 30, and 45 inches; stroke, 2 feet; the estimated I. H. P. was 720 with natural and 1,200 under forced draft. Two cylindrical boilers, with 66 square feet of grate surface, furnish the steam; the total weight of engine, boilers, and water is 110 tons for each vessel. The engines of the *Pheasant* and *Partridge* were built at the Devonport yard; those of the others by the Naval Construction and Armaments Company, at Barrow, for $47,050 for each set.

The *Pheasant* had a trial on August 11, 1888; she was very light, drawing only 8 feet 8 inches forward and 11 feet 8 inches aft (the designed mean load draught is 11 feet 4 inches). During the trial the steam pressure was 133 pounds; vacuum 25; revolutions 174; and the I. H. P. 800. Under forced draft on the same day, one trial gave an I. H. P. of 1,003 with 186 revolutions, and a second 1,200 with 194; the air pressure in fire-room was 0.75 inches. Later in the month, when loaded to within one inch of the load draught, a twelve-hour natural-draft trial showed a boiler pressure of 134 pounds; vacuum 25; and a mean I. H. P. of 824, the highest reached being 849. The patent log speed was 12 knots.

On her commission trial for three hours on November 13, 1888, the speed was 11.2 knots; the boiler pressure 130 pounds; vacuum 24; revolutions 160.5, and I. H. P. 815.

The *Partridge*, on October 10, 1888, had a twelve-hour natural-draft trial with the following results: Boiler pressure 140; vacuum 25; revolutions 170; and I. H. P. 892. As the vessel was not down to her load-line by 1 foot and 4 inches, the speed was 12.9 knots. Two days later the full-power trial came off; the vessel was lighter than before by two inches, and the speed was 13.8 knots. For the four hours the mean boiler pressure was 144.7; vacuum 23.2; revolutions 192.8; I. H. P. 1,303.

The *Peacock*, loaded to her designed draught of 10 feet forward and 12 feet 8 inches aft—mean 11 feet 4 inches—gave, on August 20, 1888, a mean boiler pressure of 139 pounds; vacuum 25.5; revolutions 164.4; I. H. P. 771, and a mean speed of 11.5 knots. On the 4th of September following, the four-hour forced-draft trial took place, the vessel being one inch lighter than before. The air pressure in fire-room was 2 inches; the boiler pressure 142 pounds; vacuum 22 inches; revolutions 189.2; I. H. P. 1,221; speed by patent log 13.5. The highest I. H. P. developed was 1,303, and the consumption of coal per I. H. P. was 2.3 pounds.

On December 7, 1888, the three-hour commission trial showed a boiler pressure of 136 pounds; vacuum 25; revolutions 172.5; I. H. P. 836, and a patent log speed of 12.7 knots.

The *Pigeon* was launched on September 4, 1888, and had a natural-draft trial on October 8. The mean draught was 11 feet 3 inches (designed, 11 feet 4 inches); for the twelve hours the mean boiler pressure was 142; the vacuum 25 inches; revolutions 170, and I. H. P. 791; the highest developed being 837. The vessel was very light at the time the full-speed trial came off next day, drawing but 8 feet 8 inches forward and 10 feet 8.5 inches ait, the boiler pressure was 142.8; vacuum 22.1; revolutions 198.9; I. H. P. mean, 1,242, maximum 1,309. During the three-hour trial when the vessel was put into commission she made a mean speed of 12.8 knots.

The *Pigmy*, launched July 27, 1888, had her natural-draft trial on November 30 at the designed load draught of water. The mean boiler pressure was 138; vacuum 26.5; revolutions 165.3; I. H. P., mean 778, maximum 838. On November 30, during the forced-draft trials, the vessel's mean draught of water was 11 feet 2 inches. The mean boiler pressure during the four hours was 142; vacuum 35.5; the mean I. H. P. 1,330, the maximum 1,349, and the measured mile speed was 13.5 knots.

The last vessel of this class, the *Plover*, was launched on October 18, 1888. A ten-hour natural-draft trial on December 7 showed a mean boiler pressure of 140; vacuum 25.5; revolutions 163.2; I. H. P. 775, and a patent log speed of 12 knots. On the following day, during the forced-draft trial, the boiler pressure was 139.9; vacuum 25.5; revolutions 197.1; I. H. P. 1279. The vessel was light, and the speed made was 13.8 knots.

MAGPIE.

The first of the improved *Pheasant* class described on p. 303, No. VII, was launched at Pembroke on March 15, 1889. In May she had both natural and forced draft trials; during the former a mean of 882 I. H. P. was developed for the 12 hours, and the speed was over 12 knots. In the latter trial the mean I. H. P. for 4 hours was 1,298, and the speed 14.13 knots.

SANDFLY—SPIDER.

Two torpedo vessels described on p. 196, No. V, and p. 306, No. VII. They were employed in last summer's manœuvres, and did not prove very satisfactory vessels at sea.

In smooth water, on June 15, 1888, with a draught of 6 feet 10 inches forward and 9 feet 6 inches aft, the *Sandfly* made a speed of 17 knots. The steam pressure in the boilers was 140 pounds; the revolutions were 300 per minute, and the I. H. P. 2,790.

After the manœuvres she underwent a thorough overhauling and refitting, and after two unsatisfactory trials in January and March, 1889, she made a speed of 19.2 in a three-hour forced-draft trial on April 11. At a reduced speed of 11.75 knots the number of revolutions per minute was 180, the I. H. P. 600, and the coal consumption per I. H. P. 2.64 pounds.

The *Spider* had a dock trial on May 19, 1888, and three days later went outside of the Plymouth breakwater. With 370 revolutions and an I. H. P. of 2,911 she is reported as making an average speed of 19.4 knots, and one run was made over the measured mile at 20.4 knots. On June 19, 1888, in a three-hour forced-draft trial, drawing 6 feet 9 inches forward and 10 feet 1 inch aft, the required I. H. P. was not obtained.

Early in March, 1889, the vessel had a forced-draught trial, drawing 7 feet forward, 10 feet 4 inches aft, mean 8 feet 8 inches, or 1 inch less than designed. The boiler pressure was 132 pounds; the pressure in cylinders, starboard, 55.8 — 30 — 11.3, port, 54 — 28.6 — 12.5; vacuum, 26.5 and 26.7; revolutions, 305; I. H. P., starboard, 415 + 477 + 433 = 1,325, port, 400 + 450 + 476 = 1,326; total mean I. H. P., 2,656, highest obtained, 2,777 (contract 3,000). Four runs over a measured mile gave the following speeds: 17.91 — 19.89 — 19.048 — 18.818; mean, 18.9165 knots.

RESEARCH.

This side-wheel surveying steamer, partially described on p. 304, No. VII, was launched on December 4, 1888. She is armed with one 7-pdr. M. L. R., and her principal dimensions are: Length, 155 feet; beam, 24 feet; displacement, 520 tons, at a mean draught of 8 feet 6 inches. The engines are oscillating; the estimated I. H. P. was 450 and the corresponding speed 9.5 knots.

On January 9, 1889, a full power trial off Sheerness, with a steam pressure of 80 pounds, a vacuum of 25.5 inches, and 40.85 revolutions, gave an I. H. P. of 541 and a speed over the measured mile of 10.95 knots.

FRANCE.

The French battle ship *Amiral Baudin* has been completed and the *Formidable* has had steam trials and is in commission; the *Marceau* and *Hoche*, laid down in 1880, are to be finished during 1889–'90, the *Magenta* and *Neptune* in 1890–'91, and the *Brennus*, laid down in 1887, is expected to be put in commission by 1893.

In consequence, the last budget does not call for any vessel of this class.

VESSELS PROPOSED OR LAID DOWN.

TRÉHOUART.

The keel of a coast-defense vessel of this name was laid at Lorient in April last. The design is by Mr. de Bussy, and she is to be of an improved *Furieux* type, but the heavy guns are to be mounted in turrets instead of barbettes. The displacement is to be about 6,800 tons. The machinery is to be built by contract.

FOUR FIRST-CLASS SIDE-PROTECTED CRUISERS.

Two of these vessels are to be built by contract, the third at the Rochefort Government yard, and the fourth is to be laid down at Toulon towards the end of next year.

The battery is to be composed of two 19-centimetre (7.48-inch) B. L., 35 calibres long, model of 1887, in bow and stern barbettes; six 14-centimetre (5.51-inch) B. L. of same model in a steel superstructure between the barbettes. On top of this superstructure are mounted four 65-millimetre and four 47-millimetre R. F. G., and in the armored tops of the two military masts eight R. C. of 37 millimetres are to be carried. The probable number of torpedo tubes is placed at six.

The engines with twin screws are to drive the ship at a speed of 19 to 20 knots under forced draft; working economically the speed is to be from 13 to 14 knots. The engines are to be built by contract.

The armor protection at the side is to be 10 centimetres (3.92 inches) thick, the barbette armor is of 8-centimetre (3.15-inch) plates laid on sufficiently inclined to make up the lack of power of resistance by that deflection.

The displacement is to be about 4,700 tons.

WATTIGNIES.

A protected cruiser (croiseur-torpilleur), with a large torpedo armament, was laid down last year at Rochefort and was given the above name.

The displacement is 1,310 tons, a slight increase over the *Condor's*, p. 260, No. VI, and p. 117, No. IV, of which she is an improved copy.

The design is by Mr. de Bussy. The engines are to be furnished from Le Creusot.

LÉGER—LEVRIER.

These two torpedo vessels, designed by Mr. Marchal, are to be laid down at Lorient this year; they will have a displacement of 450 tons, and will be of an improved *Bombe* type; the *Bombe* and class are described on p. 117, No. IV.

VESSELS LAUNCHED.

GRENADE.

An armored coast-defense gun-vessel, sister ship to the *Fusée*, described on p. 202, No. V. She was launched at Lorient on October 18, 1888.

TROUDE—LALANDE—COËTLOGON.

These third-class protected cruisers, described on p. 256, No. VI, were launched on October 22, 1888, March 21, 1889, and December 3, 1888, respectively.

VAUTOUR.

The sister ship of this vessel, the *Condor*, is described on p. 117, No. IV, and p. 260, No. VI. The *Vautour* was launched on April 25, 1889, at Toulon.

STEAM TRIALS.

FORMIDABLE.

This battle-ship (p. 114, No. IV) is a sister to the *Amiral Baudin* described on p. 43, No. V. The keel was laid at Lorient in December, 1878, so the vessel has been over ten years building; the boilers, designed to be of iron, were built of steel, and arrangements for using forced draft were introduced. The original estimated speed was 15 knots and the estimated I. H. P. 6,400; later estimates were 6,500 I. H.P. with natural, and 8,300 under forced draft.

Last February the *Formidable* had a six-hour natural draft trial off Toulon, at a mean draught of water of 26 feet 5 inches. With a boiler pressure between 63.9 and 65.3 the mean number of revolutions was 72, the mean I. H. P. 6,700, and the speed 15.2 knots.

At a four-hour forced draft trial, shortly after the above, the mean I. H. P. developed was 9,700, the revolutions were 79 per minute, and the speed 16.2 knots. In the contract for building the engines a bonus was promised for increase of horse-power over that estimated, and the contractors, Schneider & Company, Le Creusot, accordingly were entitled to the sum of 465,000 francs ($89,750).

CÉCILLE.

The vessel was built by the Société des Forges et Chantiers de la Méditerrannée. The engines, of the vertical compound type, drive two four-bladed screws. The diameters of the cylinders are 39 and 72 inches; length of stroke 3 feet 2 inches; condensing surface 15,494 square feet. Six cylindrical double-ended boilers have 36 furnaces with a grate surface of 852 square feet. The heating surface is 23,919 square feet. The total weight of machinery is 1,206 tons.

The contract calls for a speed of 19 knots; for each tenth of a knot made over this figure a premium of 10,000 francs ($1,930) is to be paid the contractors, but a forfeit of 50,000 francs ($9,650) is to be exacted if the speed falls below 18.5 knots and 100,000 francs ($19,300) if below 18.

So far the latter speed has not been realized nor has the estimated I. H. P. been developed. Different screws are to be fitted before final trials.

A preliminary trial in April, 1889, gave with 75 revolutions a speed of 15 knots; 80 revolutions, 15.49 knots; 84 revolutions, 16.25 knots; 84.95 revolutions, 16.35 knots; 89.625 revolutions, 17.29 knots; and 92 revolutions, 17.627 knots.

On May 27, 1887, a six-hour trial of machinery took place; the mean number of revolutions was 85.8, the I. H. P. was 6,348, and the speed 16.49 knots.

FORBIN.

The third-class cruiser of that name, described on p. 202, No. V, and mentioned on p. 313, No. VII, had natural and forced draft trials during last March. The first, with two boilers only, gave a speed of 10.8 knots with 70 revolutions; with fires under all four boilers the speed was 15.7 knots with 97 revolutions, showing that the vessel can cruise at 14 to 15 knots without forcing the fires. In the forced draft trial, with 129 revolutions the speed was 19.8 knots; as the estimated number of revolutions at full speed is 140, the contractors, Société des Ateliers et Chantiers de la Loire, expect to get a speed of 20 knots.

ITALY.

VESSELS PROPOSED OR LAID DOWN.

The battle-ship mentioned on page 314, No. VII, is to have about 13,000 tons displacement, and will probably be laid down in 1889–'90.

MARCO POLO.

This vessel is a protected cruiser of an improved *Etna*, or *Fieramosca* type. The keel was laid in the Government yard at Castellamare. The *Fieramosca* is described on page 263, No. VI.

LOMBARDIA—LIGURIA—ETRURIA—UMBRIA.

Of these vessels the first is building at the Castellamare yard, the others were given out to contractors; the *Liguria* to Ansaldo & Co. at Sampierdarena, near Genoa, and the others to the Orlando Brothers at Leghorn.

They are protected cruisers of the *Dogali* type, mentioned on page 314, No. VII, but in them the forecastle and poop have been extended to form a complete upper deck, making them more seaworthy and giving increased covered space.

Their batteries are composed of six 152-millimetre (6-inch) B. L. and four 120-millimetre (4.72-inch) B. L.; the latter will be of the Armstrong R. F. type, and possibly the 6-inch as well.

The vertical triple-expansion engines are to develop 6,500 I. H. P., and the estimated speed is over 20 knots. The principal dimensions are: Length, 262 feet 5 inches; beam, 39 feet 5 inches, and at the load draught of 13 feet 7 inches forward and 16 feet 7 inches aft, the displacement is to be 2,281 tons.

ARETUSA—MINERVA—URANIA—PARTENOPE—A—B.

Four of the torpedo vessels mentioned on page 315, No. VII, have been named; the three first mentioned are building in the private yards of Orlando Brothers, Ansaldo & Co., and Odero & Co., respectively; the *Partenope* and the two not yet named are building in the Castellamare yard.

They are of an improved *Tripoli* type, will have but two screws, and besides the torpedo armament will carry one 120-millimetre (4.72-inch) Armstrong R. F. G., six 57-millimetre Nordenfelt R. F. G. and two 37-millimetre R. C. The engines for the *Partenope* are to be built by Pattison in his Italian establishment at Graniti, near Naples; the estimated I. H. P. is 4,000.

VESSELS LAUNCHED.

UMBERTO I.

The *Re Umberto*, as this battle-ship was generally called up to the time of her christening and launch on October 17, 1888, was laid down at Castellamare in July,

1885. Since that time she has undergone some changes in design of armor protection, which are not yet definitely determined; the general drift of the changes are indicated on Plate III of an article on that subject in this volume.

The primary battery numbers four 13.5-inch, 68-ton B. L. mounted in pairs in two end-barbettes on midship line. Between these barbettes on the superstructure are eight 6-inch guns of the Armstrong R. F. type; four of them are sponsoned, the two forward for bow, the after for stern fire. Immediately below these, inside the superstructure, are sixteen Armstrong 4.72-inch R. F. G., eight in each broadside. Eight 57-millimetre Hotchkiss R. F. G. and ten machine guns are also carried, and eight above-water torpedo tubes will be fitted.

The estimated speed is 18 knots, the contract I. H. P. is 15,200 with natural and 19,500 under forced draft; these figures the contractors, Messrs. Mandslay Sons and Field, expect to exceed. The engines, four in number, two to each screw, are of the vertical compound type; steam will be furnished by eighteen boilers.

The protection consists of steel armor 13.7 inches thick for the barbettes and ammunition tubes, and 3.3 inches in the complete protective deck; the more recent features are complete 4 to 6-inch steel side armor in wake of battery to resist detonating shell and projectiles from R. F. G., and a triple bottom for three-fourths the length for defense against torpedoes. The spaces between the several bottoms, and between the curved protective deck and deck above are to be filled with coal.

The vessel is built of steel; has a ram-bow; one large military mast placed in the centre, two smoke-pipes forward of it and abreast of each other, and a third abaft the mast.

The principal dimensions are: Length, 400 feet 4 inches; beam, 76 feet 10 inches; displacement, 13,298 tons at a load draught of 28 feet 2 inches forward and 29 feet aft. The complement is to be 21 officers and 654 men; the approximate cost of the ship when completed is estimated as $5,107,680.

FIERAMOSCA.

At the end of August last this protected cruiser was launched at the ship-yard of the Orlando Brothers, at Leghorn. A description of the vessel will be found on page 263, No. VI.

CURTATONE.

The *Curtatone* is a third-class steel cruiser, a partial description will be found on page 264, No. VI.

The launch took place in August, 1888. at Venice, where the keel was laid in July, 1885. The vessel is now having steam trials.

The armament consists of four 120-millimetre (4.72-inch) Armstrong, and four 6-pdr. Nordenfelt, R. F. G., and two 37-millimetre Hotchkiss R. C. No torpedoes will be carried. The vessel is intended for foreign cruising service, has full sail power and only one three-bladed screw. The engine, built by R. & W. Hawthorn, is estimated to develop 1,100 I. H. P. and drive the ship at a speed of 12 knots; three boilers furnish the steam, and the bunkers hold 200 tons of coal.

STEAM TRIALS.

LEPANTO.

The general results of the trials of this battle-ship are given on page 315, No. VII; the full reports were not received in time for publication.

On account of the size of the vessel, 15,360 tons, and the use, in part, of groups of locomotive boilers, the trials are of sufficient importance to warrant a more extended description. The following notes are mostly taken from a paper read by Major Soliani before the Institute of Naval Architects last year. For the particulars regarding the locomotive boilers and their behavior, the reader is referred to the Notes on Machinery, page 366.

The *Lepanto* is a sister ship of the *Italia*, described, with plate, on page 65, No. V. As the new dock at Spezia is large enough to take these vessels, the *Lepanto* is not sheathed, and with the introduction of the locomotive boilers the number of smoke-pipes was reduced to four.

The engines were built by Messrs. Penn & Son, of Greenwich; they are of the vertical, three-cylinder compound type, four in number, two to each of the three-bladed screws. The diameter and pitch of the screws is 20 feet 6 inches; the estimated number of revolutions at maximum speed was 96 per minute, with an I. H. P. of 18,000. The diameter of each cylinder is 54 inches, and the length of stroke 3 feet 3 inches; the eight condensers have a total surface of 31,300 square feet.

The eight oval boilers have a grate surface of 478.4 square feet in their 24 furnaces, and a heating surface of 15,360 square feet; in the 16 two-furnace locomotive boilers the grate surface is 675.2, and the heating surface 26,720 square feet, giving a total grate and heating surface for all the boilers of 11,536 and 42,050 square feet. The coal carried is 1,600 tons. The trials were to be made in accordance with the following programme, proposed by Messrs. John Penn & Sons, and accepted by the Ministry of Marine:

(1) A trial with only two oval boilers lighted, and the after engines only at work on the compound system, to ascertain the most economical steaming of the ship.

(2) A trial with the eight oval boilers lighted, the four engines working compound.

(3) Ditto, with the four engines working direct expansion.

(4) A forced-draft trial, with only the after set of engines and boilers at work, the engines working direct.

(5) A forced-draft trial with all eight oval boilers and eight locomotive boilers lighted, the four engines working direct.

(6) A full-power forced-draft trial or trials, with all the engines and boilers at work, the engines working direct.

This programme was not completely carried out, on account of the ship having been put in commission, which prevented the final 18,000 I. H. P. trial being made. It went, however, far enough to show what can be expected from the engines when working at their highest power.

The trials were made along the eastern coast of the Gulf of Genoa, from Spezia to Genoa and back, the two runs being altogether of over 80 nautical miles; a portion of the forward run from Spezia to Genoa was taken in each trial, to bring up the engines to the desired speed. The speed of the ship was ascertained by means of bearings on well-known points on shore in both runs. The bottom of the ship was fairly clean, the ship having been docked on March 1, *i. e.*, about one month before the trials. The ship was fully laden in all the trials, with very slight differences of draught. The indicated horse-power developed was ascertained from the indicator cards of the main engines, without taking any account of the steam used for auxiliary purposes. The trials were carried out under the direction of Mr. J. W. Fairley and Mr. May, who represented the firm, and of Mr. Holland, the engineer in charge.

All the results obtained and the conditions of the trials are given in the table.

	Trial No. 1, April 4.	Trial No. 2, April 7.	Trial No. 3, April 11.	Trial No. 4, April 14.	Trial No. 5, April 28.	Trial No. 6, April 28.	Trial No. 7, May 5.	Trial No. 8, May 12.
Sea	Smooth	Smooth	Rather rough	Smooth	Heavy cross	Smooth	Rather rough	Smooth
Wind	Light N. E.	Light N. E.	Fresh N. E.	Light N. E.	Light S. W.	Light N.	Fresh N.	Light N.
Mean draught .... feet	30 ft. 4 in.	30 ft. 4 in.	30 ft. 3 in.	30 ft. 3 in.	30 ft. 1½ in.	30 ft. ½ in.	30 ft. 3 in.	30 ft. 4 in.
Area of midship section .... square feet	1, 999	1, 999	1, 993	1, 993	1, 984	1, 978	1, 993	1, 999
Displacement .... tons	14, 860	14, 860	14, 810	14, 810	14, 740	14, 690	14, 810	14, 860
Wetted surface .... square feet	36, 500	36, 500	36, 430	36, 430	36, 325	36, 255	36, 430	36, 500
Mean speed of ship .... knots	7. 25	13. 7	13. 3	14. 4	15. 89	16. 78	18. 18	18. 38
Indicated horse-power	1, 004	6, 230	5, 714	7, 385	10, 330	12, 010	15, 260	16, 150
Number of boilers used	2 oval	8 oval	8 oval	4 oval 8 locom.	8 oval 8 locom.	8 oval 8 locom.	8 oval 16 locom.	8 oval 16 locom.
Number of engines used	2	4	4	2	4	4	4	4
Mode of action of engines	Compound	Compound	Direct	Direct	Direct	Direct	Direct	Direct
Area of fire-grate used .... square feet	94. 1	478. 4	478. 4	Oval 239. 2 Locom. 337. 6	Oval 478. 4 Locom. 337. 6	Oval 478. 4 Locom. 337. 6	Oval 478. 4 Locom. 675. 2	Oval 478. 4 Locom. 675. 2
Heating surface used { Tubes	3, 488	13, 952	13, 952	18, 896	25, 872	25, 872	37, 792	37, 792
Heating surface used { Total	3, 840	15, 360	15, 360	21, 040	28, 720	28, 720	42, 080	42, 080
Mean steam pressure in pounds per square inch. { Oval boilers	50	54	37	52	48	51	53. 5	54. 2
Mean steam pressure in pounds per square inch. { Locomotive boilers				58	52	56	58. 5	60.
Mean steam pressure in pounds per square inch. { Engine-room	48	51	34	47	44	47	49	49
Mean air pressure in inches of water. { Oval boiler fire-rooms	Natural	0. 65 in.	0. 94 in.	1 in.	1 in.	1. 5 in.	1 in.	1. 6 in.
Mean air pressure in inches of water. { Locomotive boiler fire-rooms				1. 9 in.	1. 2 in.	2. 5 in.	2 in.	1. 9 in.
Cut-off { In H. P. cylinders	0. 1	0. 5	0. 1	0. 45	0. 175	0. 175	0. 3	0. 3
Cut-off { In L. P. cylinders	0. 6	0. 6						
Ratio of expansion	11. 1	3. 5	5. 56	1. 89	3. 93	3. 93	2. 63	2. 63
Mean pressure in pounds per square inch. { H. P. cylinders	15. 3	23	15. 4	36. 62	23. 5	26. 1	30. 65	31. 9
Mean pressure in pounds per square inch. { L. P. cylinders	6. 8	13						
Mean vacuum in condensers .... inches	28. 6	28. 7	28. 6	27.	27. 5	27. 5	27	27
Revolutions per minute	38. 8	70. 53	68. 73	74. 25	80. 95	85	92. 05	93. 5
Apparent mean slip, per cent.	6. 4	4. 25	4. 6	3. 8	2. 7	1. 8	2. 34	2. 72
Mean speed of piston per minute .... feet	252. 2	458. 25	445. 25	484. 27	526. 5	552. 5	598	607. 75

I. H. P. per square foot of grate		10.7	13	11.9	12.8	12.6	14.6	13.1	14
Heating surface per I. H. P. in square feet.	Tubes	3.48	2.24	2.45	2.55	2.5	2.17	2.46	2.34
	Total	3.82	2.47	2.69	2.84	2.78	2.41	2.74	2.61
Coal used per hour, in tons		0.9	6.4	6.9	11.4	13.7	16.8	21.8	23.5
Coal used per I. H. P. per hour, in pounds		2.02	2.27	2.75	3.45	2.97	3.14	3.2	3.3
Coal burned per square foot of grate per hour.	Oval boiler pounds	21.3	29.9	32.3	34	35	38	33	38
	Locomotive boiler pounds				51	41	58	49	51
Steam used per I. H. P. per hour as shown by indicator cards		16.1	15	18.2	22.2	18.4	18.2	21.1	20.7

The engines worked very satisfactorily all through the trials, without the slightest hitch occurring in any part of the whole machinery. This circumstance helped, no doubt, to some extent, the good performance of the boilers, which had never to be checked or hampered when in full swing.

The power of 16,150 I. H. P. on the last trial was developed by the engines with a mean air pressure of 1.9 inches of water in the locomotive boiler fire-room and of 1.6 inches in the oval boiler fire-room, the coal burnt per square foot of grate per hour being 51 pounds in the former and 38 pounds in the latter. But, as at the preliminary partial trials mentioned above the oval boilers were worked up to 2½ inches of pressure and the locomotive boilers up to 3½ inches with perfect success, burning 45 pounds and 68 pounds of coal, respectively, per square foot of grate per hour, there is evidently room left for more power.

A very good performance was that obtained on the sixth trial (April 28), when, with only two-thirds of the boilers at work, the engines developed over 12,000 I. H. P. (two-thirds of the total power), driving the ship at nearly 17 knots. The cut-off being at 0.175 of the stroke, the steam worked with a ratio of expansion 4.35, which, from the consumption of water shown by the indicator cards, appears to give the most efficient performance of the engines at great power.

A circumstance deserving notice is that all these trials were carried out with the ship's firemen, who for the greater part were not yet trained for forced draft firing.

To have more complete data of the ship and engines' performance, besides the trials above mentioned, runs were made on the measured mile to ascertain the speed of the ship corresponding to the lowest possible speed and power of the engines; also the power and speed of the engines for a speed of about 10 knots of the ship. The results are as follows:

Speed of ship, in knots	2.7	10
Revolutions	15	55
Indicated horse-power	158.6	2,403

RUGGIERO DI LAURIA.

This first-class battle-ship is mentioned on p. 118, No. IV, and partially described as a sister ship to the *Andrea Doria* on p. 203, No. V. The armament consists of four 431-millimetre (16.93-inch) 105-ton Armstrong steel B. L., model No. II, and two 152-millimetre (6-inch) steel and iron B. L., one in bow on light upper deck and one aft. Ten 57-millimetre and six 47-millimetre R. F. G., five R. C., and four Maxim guns form the auxiliary battery. The number of torpedo tubes is five, three above water, and two under water in bow.

The estimated speed was 16 knots. The vertical compound three-cylinder engines were estimated to develop 7,500 I. H. P. with natural and 10,000 under forced draft; the diameters of the cylinders are 60 and 81 inches, the length of stroke 3 feet 6 inches. The twin screws are four-bladed. Eight boilers with 48 furnaces supply the steam; the total weight of machinery is 1,207 tons and that of the fuel carried is 850 tons.

The vessel had natural and forced draft trials during April, 1889. Runs were made from Spezia to Genoa and back in courses parallel to the coast, and the speed was verified by bearings.

During the natural-draft trial the boiler pressure was from 79 to 80 pounds; the mean number of revolutions per minute, 93; the mean I. H. P., 8,100, and the mean speed 15.4 knots. The highest I. H. P. developed was 8,300.

At the forced-draft trial the mean boiler pressure was 83 pounds; vacuum, 26; revolutions, 96; I. H. P., 10,600; the greatest I. H. P. developed was 11,000. The mean speed was 17 knots and the maximum 17.5 knots.

PIEMONTE.

This vessel was launched on August 30, 1888. She was designed and built at Sir William Armstrong's works, Elswick, England, and was purchased by the Italian Government before completion.

The design was to produce a vessel of the cruiser type of the greatest speed on the smallest displacement. The vessel is built of steel; the ram is structurally strengthened by a conical swell from its point merging into the ship's lines. An excellent detailed description was given in a paper read by her designer, Mr. P. Watts, at the last meeting of the Institute of Naval Architects, and from it the following is taken:

The midship section, profile, and plans of the *Piemonte* are shown on the plate. She is 300 feet long, 38 feet broad, and 15 feet mean draught, and her displacement is 2,500 tons. She has a protective deck with sloping sides from stem to stern, which is 1 inch thick along the middle and 3 inches thick on the slopes. The armor on conning tower is 3 inches. The armament consists of six 6-inch R. F. G., six 4.72-inch R. F. G., ten 6-pdr. Hotchkiss R. F. G., six 1-pdr. R. F. G., four 10-millimetre Maxim guns, three torpedo tubes; and the speed is upwards of 21 knots.

Four of the 6-inch guns and four of the 4.72-inch guns are carried upon the upper deck, the 6-inch guns being sponsoned out so as to enable the two foremost to fire right ahead and the two aftermost to fire right astern; one of the remaining 6-inch guns is placed on the forecastle and the other on the poop. All of these guns have considerable arcs of training, as indicated on the plan. Four of the 6-pdr. R. F. G. have right-ahead fire; two of these are placed under the forecastle and two upon the after end of the forecastle; and four of the 6-pdr. R. F. G. have stern fire, two being placed under the poop and two upon the forward end of the poop. The other two 6-pdrs. and two 1-pdrs. are placed on the top sides. Each of the two lower tops carries two 1-pdr. Hotchkiss, and each of the two upper tops two 10-millimetre Maxim guns. One of the torpedo tubes fires directly ahead, and one on each broadside from a torpedo chamber immediately forward of the machinery spaces.

Provision was also made in the design for a torpedo chamber immediately abaft the machinery space, provided with a torpedo tube on each broadside, and also for a torpedo tube at the stern firing right aft, but the Italian officials preferred to dispense with these, accepting other armament weights in exchange for them.

This distribution of the gun armament has great advantages, and it has been followed in most of the cruisers built by Sir W. G. Armstrong, Mitchell & Co., including those built before the *Esmeralda*. The guns, forward and aft, have a considerable arc of training on each broadside without interfering with the fire of any of the other guns. Four 6-inch guns, three 4.72-inch guns, five 6-pdr. Hotchkiss guns, five 1-pdr. Hotchkiss guns, and four 10-millimetre guns can be brought to bear upon an enemy on either broadside; and three 6-inch guns, four 6-pdr. Hotchkiss guns, two 1-pdr. Hotchkiss guns, and two 10-millimetre Maxim guns can be brought to bear upon an enemy either right ahead or right astern.

The 6-inch and 4.72-inch guns are provided with 4.5-inch steel shields for protecting the gunners; and all of the other guns carry light shields.

The *Piemonte* is the first vessel armed with the new Elswick quick-firing gun, all of the 6-inch and 4.72-inch guns being of this pattern.

Lord Armstrong, in speaking of this gun recently, said: "The advantage of being able to fire rapidly at critical moments must be obvious to all. In the first place, the increased rapidity of the fire of each gun is tantamount to increasing the number of guns, without necessitating a corresponding increase in the number of gunners, or in the collective weight of the shields required to protect them. In the second place, we obtain the great advantage of being able to repeat a successful shot before the enemy can materially change his position, which would render necessary a fresh adjustment of the gun. These salient advantages have been fully realized in our new guns of 4.72-inch and 6-inch calibre, with both of which a rapidity of fire has been obtained hitherto considered impossible with guns of so heavy a nature. Great simplicity of design and strength of mechanism have been combined in the construction of these guns and their carriages; and with the improved descriptions of powder now coming into use velocities have been obtained so great that the 4.72-inch gun, weighing only 2 tons 1 cwt., is capable of piercing 10.5 inches of wrought iron, while the

6-inch gun, weighing 5 tons 15 cwt., can pierce 15 inches of the same material, muzzle velocities being taken in each instance.

"These guns are mounted on specially designed shielded carriages, in which exceptional facilities in handling and aiming have been combined with great protection to the gunners, and in the numerous trials carried out the shooting has been characterized not only by rapidity, but by unusual accuracy.

"The comparative rates of fire of the present breech-loading service guns, and of our new improved guns, may be judged by the following instances: In some trials carried out last year with our 4.72-inch gun by the Admiralty ten rounds were actually fired in forty-seven and one-half seconds, whereas an ordinary breech-loading gun of the same calibre, firing in competition, took five minutes and seven seconds to fire the same number of rounds. Again, the great accuracy of the guns combined with rapidity of fire is illustrated by the fact that five rounds were fired a few weeks ago at Shoeburyness, in which, at a distance of 1,300 yards, a target of 6 feet square was hit five times running in thirty-one seconds."

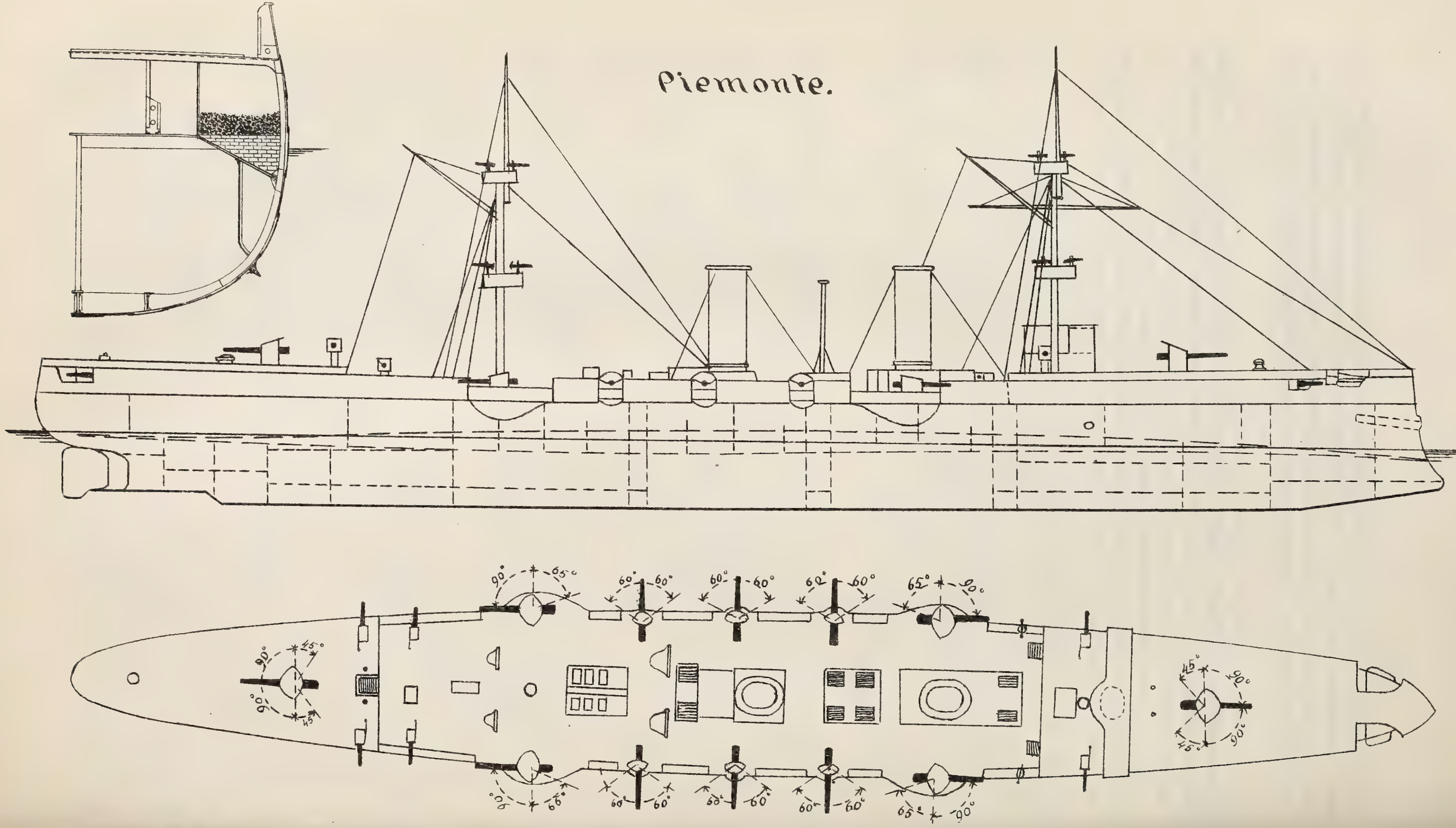
Speaking of the *Piemonte* on the same occasion, Lord Armstrong said: "She will be capable of discharging against an adversary in a given time twice the weight of shot and shell that could be fired by the largest war vessel now afloat, not excluding the leviathan battle-ships of five or six times her size, which could ill withstand the torrent of shell which the *Piemonte* could pour into the large unarmored portions of their structure."

The engines and boilers are wholly below the water-line, and protected by the armor deck; so, also, of course, are the magazines, steering gear, etc. The level of the armor deck throughout the length of the ship is shown on the profile by the dotted lines indicating the deck at middle and at side. All apertures through the armor deck which would require to be opened in action are provided with coffer-dams rising 4 feet above water.

Both below and above the armor deck the ship is subdivided into a large number of water-tight compartments. Each set of engines is in a separate compartment, and so is each pair of boilers. A series of water-tight flats form an inner bottom throughout the ship, except in wake of the boiler-compartments and the crank-pits in the engine-rooms. There are coal-bunkers along the side throughout the machinery compartment, and the inner skin is continued on forward and aft as sides to the magazines. Above the armor deck the side bunkers extend to the upper deck; and dwarf bulkheads are introduced between the main transverse bulkheads, so as to divide the bunkers into spaces varying from 10 to 12 feet long. Forward and abaft the machinery spaces there are deck flats from 2 to 3 feet above the water-line, the spaces between these and the armor deck forming a raft body, which can be packed with patent fuel, coal, or stores, as desired.

On the midship section is indicated the level of the coal above the armor deck when the normal supply of 200 tons is carried. Besides the coal on the armor deck, a quantity is stowed in the cross-bunkers, so that the ship may be in readiness for steaming at speed. Patent fuel is shown on the slopes of the deck up to the level of the top of the armor deck. Ordinary coal may be carried here, but patent fuel has advantages which are worth securing, at least to this limited extent, when it is possible to do so. The advantages are these: Patent fuel may be stowed so as practically to exclude all water, however much the side may be riddled in action, except in so far as it is blown out or otherwise removed; it is less liable to be blown out than coal by shell fire, and is much less liable to be washed out by the action of the sea through large openings made in the side; and it forms an excellent shoveling flat, down to which coal may be removed without risking materially loss of buoyancy and stability in action. With the full supply of coal the top of the armor deck is 6 inches below the water-line; but part of this full supply may consist of patent fuel or coal in sacks stowed upon the armor deck to a depth of, say, 2 feet, thus forming a continuation of the raft body forward and aft; and this fuel need not be disturbed until, by the consump-

Piemonte.


90°
65°
60°
60°
60°
60°
60°
60°
65°
90°
90°
45°
90°
45°
45°
90°
45°
90°
90°
65°
60°
60°
60°
60°
60°
60°
65°
90°

tion of the coal from elsewhere, the ship is lightened and the deck armor is raised above the water. If in this condition, with the assistance of the coffer-dams, large volumes of water can be prevented from getting below (which is not likely to be difficult, seeing that any water finding its way to holes in the coffer-dams will have but little head), and supposing the armor deck to remain intact, the buoyancy and stability of the ship may be regarded as to a very considerable extent assured even against modern shell fire.

The machinery of the *Piemonte* has been constructed by Messrs. Humphrys, Tennant & Co., Deptford, and consists of two sets of vertical triple-expansion engines. Each set has two low-pressure cylinders, and therefore acts on four cranks. The cylinders are of the following dimensions: High-pressure, 36 inches; intermediate, 55 inches; low-pressure, each 60 inches, and the stroke is 27 inches. Steam is generated in four double-ended boilers, adapted to a working pressure of 155 pounds. Draft can be supplied by eight fans, but the fire-rooms are arranged so that they can be worked, with or without forced draft. Distilling apparatus of ample power has been provided for making fresh water for the boilers, and auxiliary condensers are also fitted in each engine-room.

An auxiliary boiler stands on the protective deck amidships, capable of supplying steam to any of the auxiliary engines throughout the ship.

At a preliminary trial made on the 28th ultimo some slight defects occurred in connection with the lubrication, which necessitated some adjustments. When these defects were overcome, towards the close of the day a series of runs was made on the measured mile, with open fire-rooms and forced draft. There was very little wind on the occasion, so that much interest does not attach to the steaming without the use of the fans. Two runs, however, without the use of the fans showed that the ship could steam about 19½ knots under these circumstances. Four runs made with a moderate pressure of air in the fire-rooms, never exceeding one-quarter inch of water, gave a mean speed of 20.168 knots, with an I. H. P. of 7,760. With an air pressure of one-half inch of water, the limit fixed by the Admiralty for continuous steaming at sea, a speed of 20.3 knots could with ease be obtained with about 8,000 I. H. P. With closed fire-rooms and forced draft a power of 11,600 horses was realized. The mean of two runs, when upwards of 11,000 I. H. P. were realized, gave a speed of over 21 knots.

Twenty-one knots was the speed aimed at in the design, and the speed which is guaranteed to the Italian Government.

Whatever speed may ultimately be obtained with this vessel with forced draft, the fact that with natural draft, when the wind is favorable, or with a moderate pressure in the stokeholds, she can steam continuously in fair weather at from 20.25 to 20.5 knots has been fully established. This is regarded as of much greater importance than a very high performance with forced draft. Forced draft with high pressure in the fire-rooms—and anything above 1 inch should be regarded as high—can only be reckoned upon for a spurt of three or four hours, and at the end of this you will usually find that your boilers have more or less suffered.

The wave disturbance was remarkably small, so small was it when the ship was going upwards of 21 knots that her high speed could scarcely be realised. This was due also to the entire absence of anything like excessive vibration.

With her full coal supply of 600 tons the vessel will be enabled to steam the considerable distance of 1,950 knots at full speed with natural draft, and she will be able to maintain a cruising speed of 10 knots for fifty-five days, during which time she could cover a distance of about 13,200 knots.

On May 14, 1889, the *Piemonte* had a four-hour natural-draft trial, when a mean speed of 20.4 knots was realized with an I. H. P. of 7,040. At the forced-draft trial, which lasted one hour and a half, the mean speed was 22 knots and the I. H. P. 12,700. The highest I. H. P. developed during this trial was 12,980; the mean speed of two runs over the measured mile was 22.3 knots with 185 revolutions per minute. At both trials the ship was at her designed load draught.

MONTEBELLO.

This torpedo vessel is a sister ship of the *Tripoli*, described on p. 204, No. V; p. 264, No. VI; and pp. 225, 228, and 330, No. VII.

It is reported that she made a speed of 20.22 knots over a 4-mile course, and a mean of 17.36 knots over a 37-knot course. The number of revolutions at maximum speed was 335.

CASTORE—POLLUCE.

Two unarmored harbor-defense vessels, mounting one 120-ton Krupp B. L. each, were built at Sir William Armstrong's establishment at Pozzuoli, near Naples.

In April, 1889, they had satisfactory engine trials, but as their guns had not arrived the vessels were very light, and no account of speed was taken.

The engines are triple expansion, with cylinders 9.5, 15, and 25 inches diameter and an 18-inch stroke. The estimated speed is 8 knots with the twin screws, making 138 revolutions. One boiler supplies the steam.

The principal dimensions are: Length, 115 feet; beam, 37 feet; draught, 9 feet 6 inches; and displacement, 530 tons.

RUSSIA.

VESSELS PROPOSED OR LAID DOWN.

BATTLE-SHIP FOR THE BLACK SEA.

Proposals for designs of a new battle-ship for the Black Sea were issued in May, 1889. Prizes are to be given for the three best completed plans, and the Naval Technical Commission is to award them. All persons belonging to the navy are allowed to compete. At first preliminary designs are to be sent to the commission, and then those whose designs are not rejected are to send in complete plans within three months after the publication of the circular announcing the results of the examination of the preliminary designs.

The battery is to be composed of six 12-inch 30-calibre B. L. in three turrets, several 6-inch 35-calibre B. L., and some rapid-fire guns. Two bow, four broadside, and possibly one stern tube to form the torpedo armament.

The speed must not be less than 16 knots with natural draft. The armor is to be compound, and to consist of a partial water-line belt in wake of magazines and machinery space not less than 18 inches thick; thickness of armor on turrets and their redoubts 14 and 12 inches. The ship is to have as many water-tight compartments as possible.

The normal fuel endurance is to be five days at full speed, but the bunker capacity must be for seven days under these conditions, besides coal for galley and auxiliary engines, about 4 tons per day. The displacement is to be 11,000 tons; the principal dimensions are limited by the capacity of the large dock at Sebastopol, which has a depth of water at entrance of 27 feet; the dock-gates measure 85 feet and the length is 470 feet.

BATTLE-SHIP FOR THE BALTIC.

This vessel, of 10,000 tons displacement, is an enlarged *Alexander II* type, described on p. 267, No. VI. The Franco-Russian Company has the contract; and the ship is to be built in their yard on Galerney Island, St. Petersburg.

GHANG-OOT.

The keel of this battle-ship was laid this year, in the Admiralty yard at St. Petersburg. She is the one partially described on p. 317, No. VII, and belongs to the same type as the *Alexander II*, but has battery protection against detonating shell. The displacement is 6,600 tons.

THE XII APOSTLES.

This name was given to one of the vessels noted on p. 317, No. VII, as ordered at Nicolaieff for the Black Sea fleet.

ARMORED CRUISER.

A vessel of 9,000 tons displacement is to be built at the Baltic works; she is practically an enlarged and improved *Pamyat Azova* described on p. 206, No. V; p. 268, No. VI; and p. 318, No. VII, with heavier battery and better armor protection.

GROSIDSTCHI.

This armored gun-vessel, of about 1,500 tons displacement, has been laid down in the Admiralty yard at St. Petersburg.

POLE STAR.

An imperial yacht building at the Baltic Engineering works near St. Petersburg; the estimated I. H. P. is 6,000 and the speed 16 knots. The principal dimensions are: Length, 314 feet, beam 46 feet, displacement 3,640 tons; with a draught of 17 feet forward and 18 feet aft.

VESSELS LAUNCHED.

IMPERATOR NICOLAI I.

This battle-ship is described on p. 267, No. VI. Some changes were made during construction; steel was used in the hull; the barbette is circular; the engines will be of the triple expansion type. The battery comprises two 12-inch B. L. of 52 tons, four 9-inch B. L., eight 6-inch and two 4.2-inch B. L.; all the guns 35 calibres long. The auxiliary battery is composed of ten 47-millimetre Hotchkiss R. F. G., and eight 37-millimetre H. R. C. Seven torpedo tubes are fitted.

The launch took place on June 1, 1889.

STEAM TRIALS.

ADMIRAL KORNILOFF.

This protected cruiser was built for the Russian Government in France by the Ateliers et Chantiers de la Loire at St. Nazaire; the vessel is described on p. 206, No. V and p. 268, No. VI. The engines are of the horizontal triple-expansion type, but can be disconnected to work as compound engines. The diameters of the cylinders are 35.4, 56.7, and 83.5 inches; the length of stroke is 39⅜ inches. Steam is furnished by eight cylindrical boilers. The estimated speed was 16.5 knots with natural draft, but the vessel during a six-hour trial trip at her designed load draught made 17.5 knots, and at the forced-draft trial made 18.5 knots.

GERMANY.

The German building programme for the next five years contemplates an increase of twenty-eight vessels, and the money demanded, 116,800,000 marks ($27,798,400), was voted by the Reichstag at its last session. In the memorandum attached to the budget it was admitted that Germany does not possess a single modern battle-ship, and the necessity of an immediate beginning of the new vessels was strongly urged. The programme is carefully worked out to replace vessels of each class that are getting antiquated or worn out, by efficient and superior substitutes, besides providing for an increase in the numerical strength of the fleet demanded by the times to place Germany in the ranks of the second-class naval powers.

VESSELS PROPOSED OR LAID DOWN.

FOUR FIRST-CLASS BATTLE-SHIPS.

These are all to be laid down during the fiscal year 1889–'90, and are to be completed by 1892–'93. Their size is to be as great as possible, but is limited by the depth of water on the north German coast; consequently, the displacement will be between 9,000 and 10,000 tons. The price per vessel is estimated at 9,300,000 marks ($2,213,400).

NINE ARMORED COAST-DEFENSE VESSELS.

These are ordered in addition to the one mentioned on p. 315, No. VII; this one is designated by the letter *O*; of the new ones, *P* and *Q* are to be laid down during the fiscal year 1889–'90 and are to be completed in 1891–'92; *R* and *S* to be laid down in 1890–'91 and completed in 1891–'92; *T* and *U*, 1891–'92 and 1892–'93; *V* and *W*, 1892–'93 and completed the following year; the last, *X*, will then be laid down and finished during 1894–'95.

They will carry heavy guns in two sponsoned barbettes forward and one midship barbette aft. The protection consists of a complete armored water-line belt. To permit their employment in the shallow waters of the German coast, rivers, and canals, the draught is limited, and they have but small speed and coal capacity. The estimated cost of each vessel is 3,500,000 marks ($833,000).

SEVEN FIRST-CLASS PROTECTED CRUISERS.

In addition to the one building at Gaarden, near Kiel, mentioned on p. 315, No. VII, three, *J*, *K*, and *L*, will be laid down in 1890–'91, *M* in 1891–'92, and *N*, *O*, and P in 1892–'93; two years is the estimated time for building each vessel, and the Germans will have by 1895 ten cruisers of the *Irene* and *Prinzess Wilhelm* class described on p. 316, No. VII. The cost per vessel is 5,500,000 marks ($1,309,000).

TWO TORPEDO-VESSELS.

Both are to be built during 1889–'91 at a cost of 600,000 marks ($142,800). They have a small displacement and will be used as flag and depot-ships of torpedo flotillas.

VESSELS LAUNCHED.

SPERBER.

The sister ship of the *Schwalbe*, mentioned on p. 315, No. VII, was named as above and launched on August 23, 1888.

JAGD.

This dispatch vessel is mentioned on p. 315, No. VII, as a sister ship of the *Wacht.* She was launched on July 7, 1888.

STEAM TRIALS.

These trials, as well as all others connected with new vessels, such as manœuvring and turning, trials of guns and of all the fittings of the ship, take place off Kiel, under the direction of a permanent board of officers from the military branch of the service, thus assuring uniformity of methods and reports. An idea of the thoroughness may be gained from the fact that it takes about two months to carry out the programme of trials for a first-class cruiser. On p. 266, No. VI, will be found a condensed account of the regulations governing steam trials.

IRENE—PRINZESS WILHELM.

The first, described on p. 316, No. VII, made at one trial a mean speed of 18 knots for three hours; there was some trouble from heating in the engines, and the temperature in the fire-room was very high. In the sister ship, the *Prinzess Wilhelm,* these defects were avoided and the speed was greater.

WACHT.

At a trial this vessel, described on p. 316, No. VII, made a mean speed of 19.8 knots with an I. H. P. of 3,750; it is expected to reach a speed of 20 knots and develop 4,000 horse-power.

SPAIN.

VESSELS PROPOSED OR LAID DOWN.

ARMORED CRUISERS.

One of these, mentioned on p. 318, No. VII, as ordered at Ferrol, had the keel laid in March, 1889; the three ordered to be built by contract were given in September, 1888, to the Anglo-Spanish firm of Martinez de las Rivas and Palmer Shipbuilding Company, of Bilbao. The price for the three vessels is 45,000,000 pesetas ($8,685,000), or $2,895,000 each; the first is to be delivered two years from date of contract, the second six months later and the third six months after the second.

The speed is to be 18 knots with natural and 20 knots under forced draft. The weight of armor for each ship is about 1,000 tons. As the English firm has to get the armor in England, it is to be compound, and the contract for furnishing the armor for one and the propeller-shafts for all three was placed with Messrs. John Brown & Co., of the Atlas Works; the armor for the other two is ordered from Messrs. Charles Cammel & Co.'s Cyclops Works. The expenses of the armor tests are to be shared by the Government and the contractors.

The principal dimensions of the vessels are: Length, 365 feet; beam, 65 feet; depth, 38 feet; displacement, 7,000 tons at a mean draught of 21 feet.

SCHOOL-SHIP.

This vessel, of about 3,000 tons, was ordered by Royal decree to be built at Ferrol. She is to be used for the instruction of naval cadets, and will take the place of the *Blanca.*

GUN-BOATS.

About twenty small gun-boats of the *Condor* type, p. 321, No. VII, are ordered or building in various yards in Spain. They carry one 12-centimetre (4.72 inch) B. L. and a complement of 34 officers and men.

The principal dimensions are: Length, about 80 feet; beam, 12 feet; draught, 6 feet, and displacement, 54 tons.

About 11 knots speed is obtained with 350 I. H. P.

VESSELS LAUNCHED.

CONDE DE VENADITO.

This vessel is the last of six unprotected, third-class steel cruisers of the *Infanta Isabel* class, described on p. 208, No. V, and was launched on August 15, 1888.

STEAM TRIALS.

PELAYO.

This battle-ship, described on p. 207, No. V, and p. 271, No. VI, was built by the Forges et Chantiers de la Méditerannée at La Seyne. The original idea of applying compound armor was given up, and steel is used instead. The engines driving two four-bladed screws are of the vertical compound type; the diameters of cylinders are 38.9 and 72.4 inches; the length of stroke is 39.4 inches. Steam is furnished by twelve cylindrical, steel boilers, whose thirty-six furnaces have a grate surface of 818 square feet; the total heating surface is 23,349 square feet. The normal coal allowance is 500 tons, the bunker capacity 800.

By the terms of the contract there were to be three trials—

(1) A speed trial with natural draft, when a mean speed of 15 knots was to be made in four runs over the measured base used by the French navy. This base is 6.712 miles in length.

(2) Trial with closed fire-rooms and moderate forced draft, the air pressure not to exceed 1 inch of water, to test the working of the engines under these conditions.

(3) Trial of coal consumption. In this trial the number of revolutions was to be regulated for a speed of 12 knots, and the vessel was to steam at sea for six or more hours; the coal used during the time was to be carefully weighed and the consumption was not to exceed the rate of 70 tons for twenty-four hours.

During the trials the *Pelayo* was brought down to her load draught (mean 24 feet 1 inch); French patent fuel (briquettes d'Anzin) was used.

On August 1, 1888, the first trial took place, and with an I. H. P. of 8,000, a mean speed of 16.215 knots was realized, or 1.215 knots over the contract requirement. Experiments made on this day showed that the number of revolutions to drive the ship 12 knots was exactly 60.

The second trial took place on August 7, 1888, and the engines worked smoothly and without any hitch or interruption, but though the I. H. P. developed on the previous trial was greatly exceeded and nearly 9,600 realized, the speed was only 16.7, or about half a knot more than before. It is but fair to state, however, that the vessel's hull was designed for a maximum speed of not over 16 knots.

In the third trial, on the 11th of the month, it was found that with three-quarter boiler power and making 60 revolutions, the coal consumption was at the rate of 44 tons 5.5 cwt. for twenty-four hours.

Under these circumstances, carrying 800 tons, at maximum draught of 24 feet 9 inches aft (which permits passage through the Suez Canal), the steaming radius is about 5,000 nautical miles at 12 knots.

On August 17, 1888, the *Pelayo* was tried under half boiler power and made a speed of 13.65 knots.

CRISTÓBAL COLON.

A third-class unprotected cruiser (p. 208, No. V), built in the Government yard at Carraca was tried on May 8, 1889, and developed 1,700 I. H. P., or 200 more than estimated; the speed was 15 knots.

The engines were built by "La Maquinista terrestre y maritime" of Barcelona, Spain.

AUSTRIA.

VESSELS PROPOSED OR LAID DOWN.

KAISERIN ELISABETH.

The old wooden side-wheel steamer of that name, at present used as a torpedo transport and depot ship, will soon be stricken from the effective list and replaced by a new torpedo transport to be built for $325,000. The name is given to a first-class protected cruiser building of the type of the *Franz Josef*, described below.

Another of the type, *Cruiser C*, will be laid down.

TRABANT.

The above name was given to a torpedo vessel of the *Meteor* type and a sister vessel to the *Planet*, described below.

VESSELS LAUNCHED.

FRANZ JOSEF.

The first-class protected cruiser mentioned on p. 322, No. VII, was launched at the Stabilimento Tecnico Triestino, at S. Rocco, near Triest, on May 18, 1889.

The battery is distributed on the *Esmeralda* or *Charleston* plan; the heavy guns at the ends with a superstructure between, but these guns are much higher above the water-line and have another battery deck below them. There are two 24-centimetre (9.45 inch) 27-ton Krupp B. L., 35 calibres long, on hydraulic carriages of the Krupp pattern; each has a train of 260 degrees, and is mounted on a barbette 6 feet 4 inches high, with 3.54 inches armor protection. Six 15-centimetre (5.91-inch) 6-ton Krupp B. L., 35 calibres long, are mounted on sponsons, one each side on upper deck between the barbettes, with bow and stern fire, and two on each broadside on lower deck, the forward with bow the after with stern fire. Eleven Hotchkiss R. F. G. are also carried, and several torpedo-tubes; one is fixed in bow.

The estimated speed is 17.5 knots with natural and 19 knots under forced draft, the corresponding I. H. P. being 6,400 and 9,800. Horizontal triple-expansion engines work twin-screws, and steam is generated in four double-ended, cylindrical boilers. The coal capacity is 660 tons.

A complete protective deck, 2.24 inches thick, has above it, in wake of machinery, a cellulose belt. The vessel is built of steel, has two military masts, and a powerful ram bow. The principal dimensions are: Length, 321 feet 2 inches; beam, 48 feet 7 inches; mean draught, 18 feet 7 inches; displacement, 4,000 tons.

BLITZ—KOMET.

These two torpedo-vessels, of a type similar to the *Meteor*, were launched at Schichau's works, Elbing, Prussia, the *Blitz* in July, 1888, and the *Komet* soon after. In addition to the torpedo armament nine R. F. G. are carried. The estimated speed is 20 knots.

PLANET.

This torpedo vessel was launched by the Palmer Shipbuilding Co. at Jarrow on June 25, 1889. The armament consists of two 80-millimetre and eight 47-millimetre R. F. G.; the former are placed in the bow and stern, the latter along the side; three torpedo-tubes are placed, one fixed in the bow and two amidships on one carriage capable of discharging on either side. The estimated speed is 20.5 knots with an I. H. P. of 3,500 under forced draft. The hull is of steel, and the principal dimensions are: Length, 210 feet; beam, 23 feet; depth, 13 feet; the displacement, at a mean load draught of 8 feet 4 inches, is 480 tons. Seventy incandescent lamps are used for interior lighting.

CHILI.

In October, 1887, the Government of Chili appointed a naval commission, under the presidency of Rear Admiral Latorre, to determine the naval requirements of the state and devise a programme of new constructions, having in view the latest developments and designs in England, France, and Germany.

The commission eventually concluded to have constructed in Europe one 6,000-ton armored vessel, two fast cruisers, two gun-boats, and two torpedo-vessels, and in March, 1888, outlines were given to ship designers and builders in England, France, and Germany, and they were invited to submit plans.

VESSELS PROPOSED OR LAID DOWN.

ONE ARMORED VESSEL.

The requirements in regard to this vessel were as follows: The armament to be composed of four 24-centimetre (9.45-inch) B. L. in barbettes or cupolas and six 15-centimetre (5.91-inch) B. L. The hull protection to be a complete steel-armor water-line belt and a protective deck. The required speed was 17 knots with natural draft, and the coal capacity was to be large enough to give a steaming radius of 7,000 miles at 10 knots. Latitude was given as to arrangement of the heavy guns, but preference was expressed for four positions, or the French system of distribution.

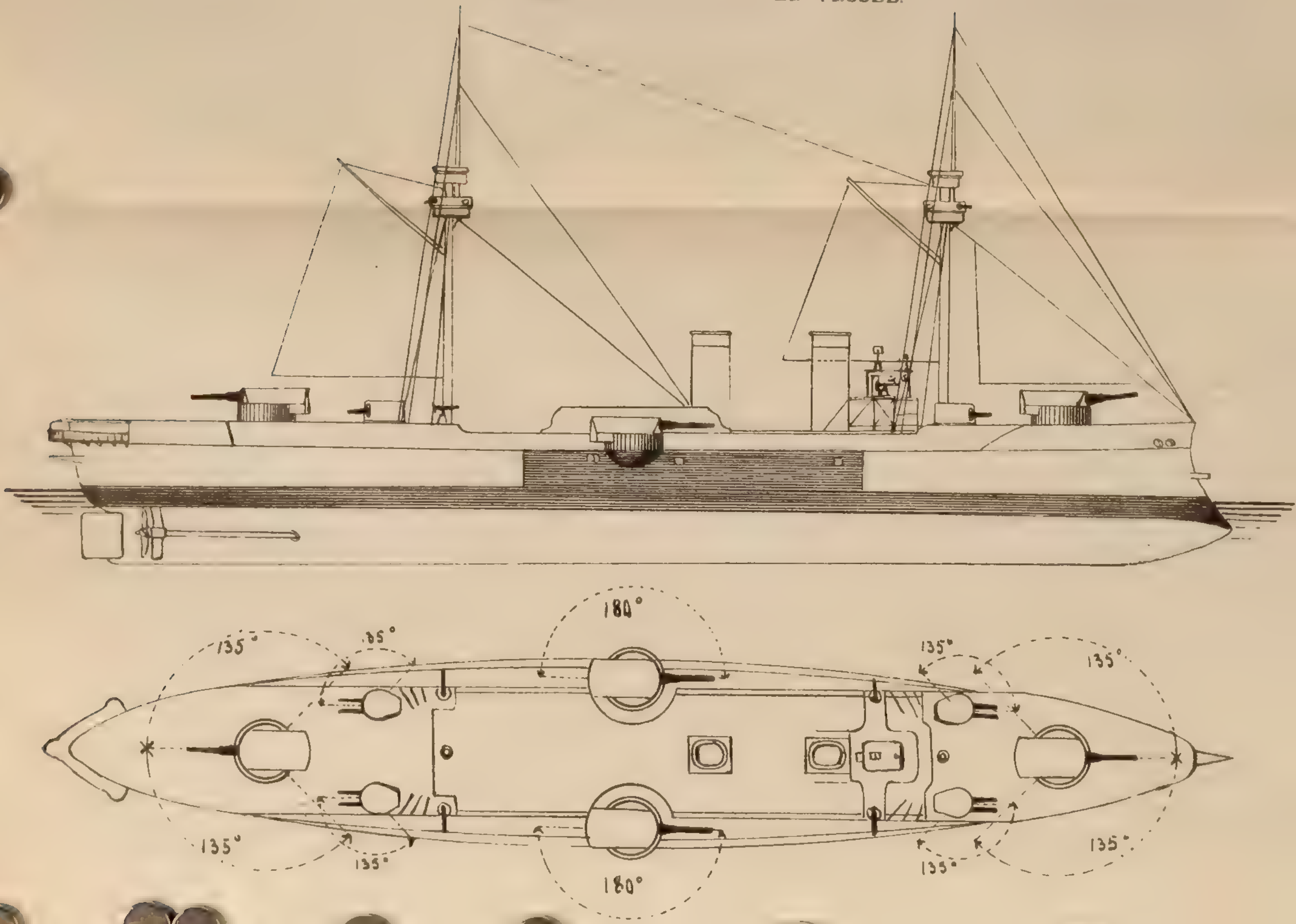
During May, 1888, nineteen plans were submitted by English, French, and German designers; in all of these the limit of displacement (6,000 tons) was exceeded. The French influence, foreshadowed above, prevailed with the commission, and all designs having the large guns in pairs, either in turrets or barbettes, were rejected; the French design of the Société des Forges et Chantiers de la Méditerranée made thin side-armor allowance for detonating shell and R. F. G. fire, and this design, somewhat modified, was given out in February, 1889, for ship-builders to base their estimates on when submitting bids for building.

The four 9.45-inch guns (see plate) are arranged on the French plan; instead of six 6-inch there are eight 12-centimetre (4.72-inch) B. L. placed in pairs in light turrets on forecastle and poop.

The estimated speed is 17 knots with natural and 19 knots under forced draft, the corresponding I. H. P. is 8,000 and 12,000. The protection for the hull consists of a complete steel water-line belt, over 6 feet 5 inches wide, with a maximum thickness of 11.8 inches; a complete protective deck, and a light central redoubt 3.94 inches thick and 134 feet 6 inches long; all armor is Creusot steel.

The principal dimensions of the vessel are: Length, 328 feet; beam, 60 feet 8

NEW CHILIAN ARMORED VESSEL.



inches; depth to upper-deck beams, 35 feet; mean draught 21 feet 10 inches, with a displacement of 6,901 tons. The weights to make up this figure are:

	Tons.
Hull	2,240
Crew, equipment, and stores	343
Armament	665
Armor, including protective-deck	2,108
Machinery, main and auxiliary	1,145
Coal	400
	6,901

Twelve ship-building firms bid on this vessel; of these seven were English, two German, and three French; the lowest bid was made by the Earle Shipbuilding Company of Hull, England, the next to them by the Société des Forges et Chantiers de la Méditerranée, and the French firm received the contract to build the ship for £391,000 ($1,902,800).

TWO PROTECTED CRUISERS.

The contract for building these vessels was given to the same firm. They are small vessels, carrying four 15-centimetre (5.91-inch) and two 12-centimetre (4.72-inch), all French type, 36-calibre B. L. Three torpedo tubes are to be mounted, and the auxiliary battery numbers four 57-millimetre Hotchkiss R. F. G., four 37-millimetre R. C., and two 11-millimetre Gatlings.

The contract speed is 17 and 19 knots, natural and forced draft; the corresponding I. H. P. 3,550 and 5,400. Horizontal triple-expansion engines work twin-screws; four three-furnace boilers supply the steam. The estimated steaming radius is 4,500 knots at a speed of 12 knots.

The vessels are to be built of steel and have protective decks with cellular belts or coffer-dams; they were originally designed with sail power and a speed of 16 knots, but masts and yards were given up for greater steaming speed.

The principal dimensions are: Length, 268 feet 4 inches; beam, 35 feet 9 inches; depth, 23 feet 5 inches; mean draught, 14 feet 5 inches, with a displacement of 2,080 tons. Both vessels are to be sheathed.

TWO GUN-VESSELS.

They are to be of about 800 tons displacement, and have also been given to the Société des Forges et Chantiers de la Méditerranée to build.

TWO TORPEDO-VESSELS.

These vessels are of the English *Sharpshooter* type, p. 303, No. VII, of 735 tons displacement, and are ordered in England from Laird Bros., at Birkenhead.

DENMARK.

VESSELS LAUNCHED.

VALKYRIEN.

The protected cruiser of the second class, described on p. 276, No. VI, was launched on September 9, 1888. The contract for the protective-deck armor was given to Schneider & Co., Le Creusot, France.

GREECE.

The Government of Greece some time ago applied to that of France for the assistance of experts to serve on a commission to formulate a building programme to strengthen the Grecian navy, and to design vessels of the type required. The French Admiral Lejeune was in consequence placed at the head of this commission, and was assisted principally by the constructing engineer, Mr. M. Dupont, who is the designer of the following vessels:

VESSELS PROPOSED OR LAID DOWN.

BATTLE-SHIPS.

Three second-class battle-ships were ordered from the Société des Forges et Chantiers de la Méditerranée, who are building two of them at Graville.

VESSELS LAUNCHED.

HYDRA.

The contract for the third vessel of the type was sublet to the Société des Ateliers et Chantiers de la Loire, and she was launched at their St. Nazaire yard on May 15, 1889.

The battery is composed of two 27-centimetre (10.6 inch) B. L. of 36 calibres in barbette, one each side, on top of an armored casemate in forward part of ship; and one of 30 calibres length in a circular armored barbette aft; four 15-centimetre (5.91-inch) B. L. 36 calibres, are mounted in the four corners of the casemate, and one in barbette above it, on forward part and between the heavy guns. Three torpedo tubes are fitted, one in bow and one in each broadside. The auxiliary battery comprises seven 57-millimetre R. F. G., and sixteen 37-millimetre R. C.

The horizontal triple-expansion engines are to develop 6,700 I. H. P. under forced draft, and the estimated maximum speed is 17 knots. The protection consists of a complete water-line belt of Le Creusot steel of 11.8 inches maximum thickness, tapering to 4.72 inches; a casemate, nearly rectangular in shape, with 13.7 inches of armor, and 11.8 inches on the barbette aft. The complete protective deck is of four thicknesses of 0.49-inch plates, or 1.97 inches in all; above the armor belt is another 2.95 inches thick for protection against detonating shell. The armor for this and the protective deck is from the firm of Châtillon et Commentry. Behind the side armor is a cellular coffer-dam, and the coal-bunkers are next to this. The hull is divided into 118 water-tight compartments.

The vessel is built of steel, has a ram bow, and is fitted with three military masts. The principal dimensions are: Length, 234 feet; beam, 51 feet 10 inches; depth, 29 feet 8 inches, and displacement 4,885 tons.

HOLLAND.

VESSELS PROPOSED OR LAID DOWN.

The Dutch Chamber adopted the naval budget last December and authorized the construction of one small armored vessel of the *Monitor* type for river service in the Indian Netherlands.

The minister of marine has drawn up a programme for improving the Dutch navy, which calls for four armored vessels and sixteen torpedo-boats.

JAPAN.

VESSELS PROPOSED OR LAID DOWN.

SHIODO.

This vessel was ordered last year from Messrs. Thomson, of Glasgow, to replace the lost *Unebi.* The principal dimensions are: Length, 300 feet; beam, 41 feet; displacement, 2,400 tons. The armament is composed of eleven 12-centimetre (4.72-inch) B. L. and three torpedo tubes. The contract speed is 19 knots and the coal capacity 240 tons.

VESSELS LAUNCHED.

ITSUKUSIMA.

One of the two armored coast-defense vessels described on p. 278, No. VI, and mentioned on p. 324, No. VII, is to be launched at La Seyne by the Forges et Chantiers de la Méditerranée on July 11, 1889. The vessels were designed by Mr. Bertin.

YAEYAMA.

The dispatch vessel built by the Japanese Government at the Yokosuka yard was launched in the early part of this year.

Three 12-centimetre (4.72-inch) B. L., six machine guns, and two torpedo tubes form the armament. The estimated speed is 20 knots and the I. H. P. 5,400 under forced draft. The principal dimensions are: Length, 315 feet; beam, 34 feet 6 inches; depth, 15 feet 5 inches; displacement, 1,600 tons at a mean draught of 15 feet.

TAKAO.

A cruiser, mentioned on p. 211, No. V, as building at the same yard, was launched last year. The armament comprises four 15-centimetre (5.91-inch), one 12-centimetre (4.72-inch) B. L., and two torpedo tubes. Two horizontal compound engines are to develop 2,300 I. H. P., and the corresponding speed is to be 15 knots. Two cylindrical boilers supply the steam. The principal dimensions are: Length, 229 feet; beam, 34 feet; displacement, 1,764 tons at a mean draught of 13 feet.

F. Singer,
Lieut. U. S. N.

MACHINERY.

There have been but few changes in the general design of machinery for vessels of war during the past year. The compound engine has been completely superseded by the triple-expansion type, while the quadruple-expansion has not yet been adopted in war ships.

To avoid the uneconomical working of high-speed engines at low powers, the Russian Government has adopted a device patented by M. Paul de Buit, manager, and M. P. Sabathier, engineer in-chief, of the Société des Usines Franco-Russes, St. Petersburg, and is fitting it to the engines of the *Nicolas I.* In this arrangement the order of the cylinders is reversed, the low-pressure cylinder being forward. This necessitates a longer steam-pipe, but in small ships with horizontal engines it is advantageous in that the smallest cylinder is furthest aft, where the beam of the ship is less and the dead rise more. The crank-shaft is made in two sections, with the coupling disks between the intermediate and low-pressure cylinders. Instead of coupling in the usual manner by bolts, each disk is fitted with a pin, and these pins are connected by a short double-bar drag-link. When disconnected the pin in the intermediate crank-shaft coupling disk is withdrawn, permitting the revolution of the shaft without interference with that of the low-pressure cylinder. The removed pin is utilized in securing the free end of the link to the disk to which it is attached. Valves are fitted between the intermediate and low-pressure cylinders, between the low-pressure cylinder and the condenser, and between the intermediate-pressure cylinder and the condenser, permitting the low-pressure cylinder to be thrown entirely out of action. The engine is then worked as a compound engine for low powers. The link connection is used to avoid trouble from the imperfect alignment of the shafts, which is apt to occur when one part of the engine has been at work while the other has remained at rest. Coupling and uncoupling can be done in two minutes. The patents cover another method of connection, dispensing with the link, which is applicable to small powers, but the one above described is that with which the larger type of engines are to be fitted.

Drawings for a similar coupling, so far as it related to a lack of alignment between the shafts, were made in the Bureau of Steam Engineering in 1882, for the U. S. S. *Juniata.* No means were employed for the removal of the pins, however, so that independent revolution of one part was impossible owing to interference with the other.

The machinery of the armored cruiser *Maine,* 6,600 tons displacement, will consist of two propelling engines placed in water-tight compartments and separated by a fore and aft bulk-head. These engines will be of the vertical inverted-cylinder direct-acting triple-expansion type, each with a high-pressure cylinder 35½ inches, an intermediate-pressure cylinder 57 inches, and a low-pressure cylinder 88 inches in diameter; the stroke of all pistons being 36 inches. The collective indicated horse-power of propelling, air-pump, and circulating-pump engines will be 9,000 when the main engines are making about 132 revolutions per minute. All cylinders will be steam jacketed. The high-pressure cylinder of each engine will be aft and the low-pressure cylinder forward; the low-pressure cylinders being so arranged as to be disconnected when working at low power. The main valves will be of the piston type, worked by Stephenson link motions with double-bar links. The piston-valves, valve-liners, and valve-gear will be made interchangeable. There will be one piston-valve for each high-pressure cylinder, two for each intermediate-pressure cylinder, and three for each low-pressure cylinder. Each main piston will have one piston-rod, with a cross-head working in slipper guides. The framing of the engines will consist of hollow cast-steel columns, trussed by forged-steel stays. The engine bed-plates will be of cast-steel, supported on wrought-steel keelson-plates built in the vessel. The crank-shafts will be made in interchangeable sections. All shafting will be hollow. The shafts, piston-rods, connecting-rods, and working parts generally will be forged of mild open-hearth steel.

The condensers will be made entirely of composition and sheet-brass. Each condenser will have a cooling surface of about 7,010 square feet, measured on the outside of the tubes, the water passing through the tubes. For each propelling engine there will be a double, horizontal, double-acting air-pump worked by a vertical compound engine. The circulating-pumps will be of the centrifugal type, one for each condenser, worked independently.

The propellers will be three-bladed, right and left, of manganese or aluminum bronze, or approved equivalent metal.

There will be eight single-ended steel boilers of the horizontal return fire-tube type, 14 feet 8 inches outside diameter and 10 feet long, constructed for a working pressure of 135 pounds per square inch. They will be placed in two equal groups in two water-tight compartments, with one fore and aft fire-room in each compartment. Each boiler will have three corrugated furnace-flues, 3 feet 6 inches internal diameter. The total heating surface will be about 18,800 square feet, measured on the outer surface of the tubes, and the grate surface 553 square feet. There will be in each boiler compartment an approved vertical duplex main feed-pump, and a duplex auxiliary feed-pump. Each main and auxiliary feed system will be complete in itself. There will be two smoke-pipes, one for each compartment.

The forced-draft system in each compartment will consist of two blowers, which will discharge into a main air-duct under the fire-room floors, from which a branch duct will lead to the ash-pit of each furnace. Means will be provided for closing the ash-pits when under forced draft and for preventing leakage of gases out of the furnace doors. The draft to each furnace will be regulated by means of a damper.

There will be steam reversing-gear, ash-hoists, turning-engines, auxiliary pumps, engine-room ventilating-fans, a combined windlass and capstan, steam-winches, a steering-engine, engines and dynamos for working various small machinery and for lighting, hydraulic pumping plant for various purposes, turret-turning engines, a distilling apparatus, and such other auxiliary or supplementary machinery as may be specified.

The machinery of the armored battle-ship *Texas*, 6,300 tons displacement, will be of the same type as that of the *Maine*. The cylinders will be 36, 51, and 78 inches diameter by 39 inches stroke. The collective indicated horse-power of propelling, air-pump, and circulating-pump engines will be 8,600 when the main engines are making about 123 revolutions per minute. The high-pressure cylinder of each engine will be forward. The valves for the high and intermediate-pressure cylinders will be of the piston type, one for each cylinder. There will be one double-ported balanced slide-valve for the low-pressure cylinder. The framing of the engines will consist of cast-steel inverted **Y**-frames, trussed by forged steel stays.

The condensers will be made entirely of composition and Muntz metal plates, with a cooling surface of about 6,462 square feet each. For each propelling engine there will be a double, vertical, single-acting air-pump worked by a vertical compound engine.

The propellers will be four-bladed, right and left, of manganese or aluminum bronze, or approved equivalent metal.

There will be four double-ended steel boilers of the horizontal return fire-tube type, 14 feet mean outside diameter and 18 feet mean length, constructed for a working pressure of 150 pounds per square inch. They will be placed in four water-tight compartments with two athwartship fire-rooms in each compartment. Each boiler will have six corrugated furnaces, 3 feet 3 inches internal diameter. The total heating surface will be about 16,913 square feet, and the grate surface about 532 square feet.

The forced-draft system will be the closed stokehold system, air being supplied by two blowers. There will be the usual small engines for various purposes. The reversing engine will be hydraulically controlled.

The machinery of the twin-screw armored coast-defense vessel of 4,000 tons displacement will be of the same type as the preceding, with cylinders 27, 41, and 64 inches diameter by 30 inches stroke. The collective I. H. P. of main, air-pump, and circulating-pump engines will be 5,400 when the main engines are making about 150 revolutions per minute. They will be fitted with interchangeable piston-valves worked by Stephenson links, one for the high and two for each of the other cylinders. The framing, bed-plates, and working parts as in the *Texas*.

The condensers will be entirely of composition, with about 3,848 square feet of cooling surface. The air and circulating pumps as in the *Texas*.

The propellers will be three-bladed, right and left, of manganese or aluminum bronze, or approved equivalent metal.

The novel feature of this design is found in the boilers. There will be two single-ended steel boilers of the horizontal return fire-tube type, about 11 feet 2 inches outside diameter and about 10 feet 7 inches long, and such "tubulous," "sectional" or "coil-boilers" as may be determined by the Navy Department hereafter, all constructed for a working pressure of 160 pounds per square inch. They will be placed in two groups in two water-tight compartments separated by a middle-line bulkhead. Each of the two horizontal return fire-tube boilers will have two corrugated furnace-flues, 3 feet 6 inches internal diameter. The total heating surface of the two cylindrical boilers will be about 2,840 square feet, and the grate surface 88 square feet; in each compartment there will be a main and an auxiliary feed system, each complete in itself. There will be one smoke-pipe. The forced-draft system will be that of the closed ash-pit, with one blower in each compartment. The usual small engines for various purposes will be fitted as designated.

The two 3,000-ton protected cruisers, Nos. 7 and 8, are to have two four-cylinder, vertical, triple-expansion engines, driving twin-screws. The cylinders will be 36, 53, 57, and 57 inches diameter by 33 inches stroke. The cranks will be 90 degrees apart, the two low-pressure ones 180 degrees apart. The cylinders will be fitted with piston-valves, one to the high-pressure cylinder and two to each of the others, all worked by the Stephenson link motion. The indicated horse-power of each main engine, including that of its air-pump and circulating-pump engines, will be 5,000, or a total collective indicated horse-power of 10,000, giving an estimated speed of over 19 knots per hour.

The pumps and other details will be practically the same as in the previously mentioned vessels.

A novelty of design worthy of special mention is the method to be employed to allow for the expansion and contraction of the large copper pipes; instead of the ordinary slip joint, sections of corrugated copper pipe are to be introduced. In a 28-inch inside diameter, No. 7 B.W. G. copper exhaust pipe, there are to be five double corrugations, semicircular in section above and below the centre line of corrugations, with centres 4 inches apart. The expansion section will therefore occupy 40 inches in length of pipe.

For cruisers Nos. 9, 10, and 11, of about 2,000 tons displacement each, the machinery will be of the vertical, triple-expansion type, with cylinders 26½, 39, and 63 inches diameter, by 26 inches stroke. The collective horse-power, including pump engines, will be 5,400 when the main engines are making about 185 revolutions per minute.

The main condensers will have, each, a cooling surface of about 3,957 square feet, with independent pumps as in the other ships. There will also be in each engine-room an auxiliary condenser of sufficient capacity for all the auxiliary machinery, each condenser being connected to all the auxiliary machinery. Each of these condensers will have a combined air and circulating pump.

There will be three double-ended steel boilers of the horizontal return fire-tube type, two of them about 11 feet 8 inches in diameter and about 18 feet 1 inch long, and the other of the same diameter and about 18 feet 8½ inches long; and two single-ended steel boilers of similar type of the same diameter and about 9 feet ½ inch long, and constructed for a working pressure of 160 pounds per square inch. They will be placed in six water-tight compartments. Each of the three double-ended boilers will have four, and each of the two single-ended boilers will have two corrugated furnace-flues of 3 feet 6 inches internal diameter. The total heating surface will be about 10,966 square feet, and the grate surface 336 square feet. There will be in each middle boiler compartment a main feed-pump, and in each after boiler compartment an auxiliary feed-pump. Each main and auxiliary feed system will be complete in itself. There will be two smoke-pipes.

The forced-draft system will be that of the closed ash-pit, with one blower in each compartment.

The usual small engines for various purposes will be fitted as designated.

As original designs for machinery for cruisers Nos. 7, 8, 9, 10, and 11 have been invited, and as the contracts are not yet awarded, it can not be stated at this time whether the vessels will be provided with machinery of the Department's design, described above, or not.

The piston speeds at maximum power and the cylinder ratios for the above, are given in the following table:

Vessel.	Stroke of piston in inches.	Revolutions per minute.	Speed of piston in feet per minute.	Cylinder ratios.		
Maine	36	132	798.0	1	2.578	6.145
Texas	39	123	799.5	1	2.007	4.695
Coast defense vessel	30	150	750.0	1	2.306	5.619
Cruisers Nos. 7 and 8	33	164	902.0	1	2.168	5.014
Cruisers Nos. 9, 10, and 11	26	185	801.7	1	2.166	5.652

In the President's inaugural address to the Northeast Coast Institution of Engineers and Ship-builders, delivered the 3d of October, 1888, Mr. F. C. Marshall says:

"So much depends on the 'human factor' in all questions of this nature, that it is very doubtful if the present system of running war ships at this most economical rate, which is very slow, when on their passages from port to port, is at all a wise one. Clearly what is wanted is that the engineer officers of all grades should be made as efficient as possible, and the most advantageous course to this end, even from an economic point of view, seeing that frequent manœuvres are very costly to the country, would be that all our war ships should make their passages at full speed, so as to accustom the engine-room and boiler-room staffs to all the exigencies and requirements of working their engines and boilers at full power and speed.

"Contractor's trials * * * are *emergency* trials under forced-draft pressure of two inches of water, but the full power at sea for continuous running is considered to be that due to an air-pressure of a quarter to half inch of water (and that is in most ships about double the funnel draft), and at this rate there can be no question the engines and boilers of our war ships could be as safely worked at their sea-going full power as any merchant vessel for as long a time as their coal supply lasted."

ADMIRALTY REGULATIONS CONCERNING USE OF FORCED DRAFT IN H. M. SHIPS.

The Admiralty have issued a new section to the Queen's regulations with reference to the use of forced draft in Her Majesty's ships. The substance of the changes was embodied in the annual statement of the first lord, but the full text of the order is as follows:

(1) In ships fitted with closed stoke-holds and fans, the term "natural draft" or "open stoke-holds" implies that the air required for combustion, ventilation, etc., is supplied by the fans, but with little or no pressure (as indicated by the water-gauge), and with the stoke-hold doors open or closed, as may be found desirable.

(2) It will probably be found more convenient, when under steam, to keep the stoke-holds closed, and to use the fans, their speed being regulated as required to supply the air necessary for the fires and the proper ventilation of the boiler-rooms.

(3) It is to be distinctly understood that forced-draft appliances are not to be used at their full power, or, in other words, above the ½-inch pressure, except in circumstances of emergency, and then only for short periods, when the maintenance of the highest possible speed for three or four hours may be of great advantage.

(4) The same appliance must be made use of, however, under most conditions, for securing the proper supply of air to the boiler-rooms when vessels are steaming at moderate speeds; and within the limits of their pressure mentioned in clause 5 the boilers may be worked continuously over the full period for which coal is carried.

(5) The specified natural-draft power can usually be obtained with an air pressure not exceeding one-half inch of water, and this is to be considered the full power of continuous steaming at sea. The boilers and engines are not to be forced beyond this, except in cases of emergency, as explained in clause 3.

(6) During the quarterly passage trials at sea the engines are to be worked up gradually to this specified natural-draft power, which should be maintained continuously throughout the four hours' trial, the air pressure not being allowed to exceed one-half inch of water.

(7) The maximum specified power with forced draft is obtained with air pressure of 1½ inches to 2 inches of water, and this is specially provided to be applied in cases of emergency, and for very short periods only. On general service the boilers are never to be forced to this extent, except under the direct orders of the commander-in-chief, who will, in his report of proceedings, explain why the special orders were given.

(8) The indications of the air-pressure gauges are to be recorded in the engine-room registers every hour.

(9) The fans are not to be used for the purpose of rapidly urging the fires and raising the steam quickly, and all the instructions in the "Steam Manual" as to the necessity of avoiding rapid changes in the pressure of the steam and the temperature of the boilers are to be strictly followed.

(10) It is important that the boilers should be supplied with fresh water only, so as to avoid the deposit of solid matter on the heating surfaces; and the instructions respecting the cleanliness of the boilers must be strictly followed. Special attention should be paid to maintain the efficiency of the double distillers or evaporators, which are provided for the supply of fresh water. Sea water should never be used for feeding the boilers unless absolutely necessary.

(11) The instructions in clauses 5, 6, and 7 are not to apply to torpedo gun-boats, or other vessels with locomotive or special types of boilers, for which special instructions are given in the "Steam Manual."

PERFORMANCE OF THE LOCOMOTIVE BOILERS OF THE LEPANTO.

In April and May, 1888, a series of steam trials of the Italian battle-ship *Lepanto* was made in the Gulf of Genoa.

Major Nabor Soliani read a paper on the subject before the Institution of Naval Architects, at Glasgow, July 26, 1888; from which are extracted the following remarks on the working of locomotive boilers in battery:

"After the rather discouraging experience with locomotive boilers working in sets on board some ships, as the *Flavio Gioja*, of the Royal Italian navy, and the *Polyphemus*, of the Royal English navy, some fear was entertained that similar troubles might be experienced with the *Lepanto*, in which the difficulty appeared to be still greater, considering the larger number of boilers to be worked together in so many different separate compartments.

"But nothing of the kind happened; nay, everything went to prove the contrary.

"From the very beginning of the preliminary trials, which took place toward the end of last year, the locomotive boilers gave evidence of their good working, which went on increasing trial after trial, so as to be now an established fact.

"They never primed or gave any trouble whatever. The feeding was occasionally uncertain, but the fault was due to air that collected in the main feed-pipe. This imperfection was removed, and on the last two trials the feeding was quite satisfactory. After each one of the last three forced-draft trials the locomotive boilers had tubes leaking, but in small number, and not more, comparatively, than the oval boilers, which even in this respect did not behave better. Moreover, there were discrepancies between the different compartments of boilers, locomotive as well as oval, which show that the management of the fires has a good deal to do in this matter.

"The ventilation of the locomotive stoke-hold is excellent. The fans being fitted on top of the boilers, no current of air strikes the floor, and a thorough cool ventilation and forced-draft are obtained without any inconvenience whatever from coal-dust. The same may be said of the oval-boiler stoke-hold, where the fans are fitted on the wings behind the boilers; but, although the supply of air is ample, the temperature does not during forced-draft fall so low, probably on account of the boilers facing each other. The mean temperature of the oval-boiler stoke-holds was about 106°, against 88° in the locomotive-boiler stoke-holds, while the atmospheric temperature oscillated about 58°.

"The engines worked very satisfactorily all through the trials without the slightest hitch occurring in any part of the whole machinery. This circumstance helped no doubt to some extent the good performance of the boilers, which had never to be checked or hampered when in full swing.

"The power of 16,150 I. H. P. on the last trial was developed by the engines with a mean air pressure of 1.9 inches of water in the locomotive-boiler stoke-hold, and of 1.6 inches in the oval-boiler stoke-hold, the coal burnt per square foot of grate per hour being 51 pounds in the former and 38 in the latter. But as at the preliminary partial trials mentioned above the oval boilers were worked up to 2½ inches of pressure and the locomotive boilers up to 3½ inches with perfect success, burning 45 and 68 pounds of coal, respectively, per square foot of grate per hour, there is evidently room left for more power. The gain in speed which would follow such increase of power is, however, not very great, as is clearly apparent from the results of the last two trials.

* * * * * * *

"A circumstance deserving notice is, that all these trials were carried out with the ship's stokers, who for the greater part were not yet trained for forced-draft stoking."

The *Lepanto* has six compartments for boilers, three forward of the forward engines and three abaft the after engines. Beginning forward, the first compartment contains four locomotive boilers, the second the same, the eight boilers having one elliptical funnel; the third compartment contains four oval boilers, the four having one elliptical funnel. Abaft the engines, the first compartment contains four oval boilers having one elliptical funnel, the second and third compartments contain eight locomotive boilers, four each, having one elliptical funnel. The axes of the locomotive boilers are fore and aft of the ship, and those of the oval boilers athwartship, as also are the longer diameters of all the funnels.

In the locomotive boilers, in which alone we are for the present interested, there are two furnaces in each boiler, separated by a longitudinal water space, which, however, stops short of the tube-plate, leaving a passage between, above the bridge. The furnaces are just as long as the fire-grate, but to prevent the fire damaging the tubes and to ensure a good combustion of the gases a high hanging, inclined, baffle, brick bridge is fitted, as usual in railway practice, in each furnace at the end of the fire-grate. The bottoms of the ash-pits form water-pans to keep the grates cool; the latter are made with longitudinal cast-iron rocking-bars. The boiler-rooms are provided with twenty fans—four in each oval-boiler room and three in each locomotive-boiler room—capable of maintaining an air pressure of over 2½ inches of water in the former and of 4 inches in the latter.

The following are the leading particulars of the locomotive boilers:

Boilers—	
Number	16.
Height	9 ft. 6 in.
Width in front	7 ft. 11 in.
Length	14 ft. 5 in.
Diameter of barrel	6 ft. 7 in.
Furnaces—	
Number in one boiler	2.
Width	3 ft. 3 in.
Length	6 ft. 8 in.
Height of crown above fire-grate	6 ft.
Capacity of furnaces in one boiler	260 cu. ft.
Grates—	
Length of grates	6 ft. 6 in.
Grate area in one boiler	42.2 sq. ft.
Arrangement of fire-bars	Longitudinal rocking.
Material of fire-bars	Cast iron.
Type of fire-bars	Having side inclined combed air-grooves.
Tubes—	
Number in one boiler	376.
Material	Brass.
Length between the plates	7 ft. 7 in.
Diameter, internal	1¾ in.
Diameter, external	2 in.
Area through tubes in one boiler	6.27 sq. ft.
Heating surface in one boiler, tubes	1,490 sq. ft.
Heating surface in one boiler, total	1,670 sq. ft.
Total for all sixteen locomotive boilers—	
Grate area	675.2 sq. ft.
Heating surface, tubes	23,840 sq. ft.
Heating surface, total	26,720 sq. ft.
Area through tubes	100.3 sq. ft.
Water surface	1,412 sq. ft.
Capacity of furnaces and combustion chambers above fire-grates	4,160 cu. ft.
Capacity of steam chambers	3,360 cu. ft.
Weight of water	105.6 tons.
Funnels—	
Number of funnels	2.
Size (oval)	6 ft. 4 in. by 8 ft. 2 in.
Height above fire-grate	72 ft.
Area	94 sq. ft.
Ratio of grate area to—	
Tube heating surface	35.3.
Total heating surface	39.6.

Ratio of grate area to—	
Area through tubes	0.15.
Area of funnels	0.14.
Water surface	2.09.
Capacity of steam chamber	4.98.
Capacity of furnaces and combustion chambers	6.16.
Load on safety-valves	60 lbs.
Fans—	
Number	12.
Diameter { four	4 ft. 6 in.
Diameter { eight	6 ft. 0 in.
Type of fan engines	Brotherhood.

(For other information concerning *Lepanto* see p. 344.)

THORNYCROFT'S WATER TUBULAR BOILER.

A drawing and detailed description of this boiler will be found in General Information Series, No. VII.

The following extracts concerning it were taken from a paper read before the United Service Institution, Feb. 15, 1889, by John Donaldson, M. Inst. C. E., entitled "The more recent Improvements in the Thorncroft Torpedo-Boats."

The first "Thornycroft" boiler was fitted to the steamer *Peace*, belonging to the Baptist Missionary Society, in 1883, for service on the Congo.

After a service of five years, the Rev. Mr. Grenfell, the missionary in charge, writes to the Messrs. Thornycroft:

"The boiler itself is doing splendidly, and we have no difficulty in keeping up steam sufficient for 400 revolutions—in fact, quite steam enough for any purpose, and when head to wind often too much."

To show that skilled labor is not required either in the assembling of the boiler or in its management when in place, the following is cited: The steamer *Peace* was completed toward the end of 1882, tried on the Thames, was then taken to pieces, packed, and sent to the Congo. On this occasion all the tubes were taken out of the boiler, as the weight of each package was, as far as possible, restricted to 64 pounds.

The vessel and its boiler were re-erected there by the missionary and his black assistants, and set to work in the spring of 1884, since which time it has been running with the success already mentioned.

A second-class torpedo-boat, No. 100, fitted with a "Thornycroft" boiler, was running on the Thames in 1886, and was delivered to the Admiralty in August of that year, so that the boiler has been in use a little less than three years. Latest accounts report the boiler as giving continued satisfaction.

In speaking of this boiler, Captain Nielsen, Director of Naval Construction of the Royal Danish navy, writes:

"In the torpedo-boats ordered during the last two years from your firm for the Danish navy, you will remember the boilers are of 'Thornycroft' patent tubulous type; thus two tubulous boilers have been fitted in each of the first-class torpedo-boats, *Narhvalen*, *Havhesten*, *Storen*, and *Soloven*, and one boiler in each of the four second-class torpedo-boats and four patrol boats.

"These boilers have up to this date never given any trouble; steam can be put up in less than half an hour without risking any leakage by sudden variation in temperature.

"They are splendid steam generators; the air-pressure at full speed does not exceed 1 inch to 1½ inches in the large boats.

"The engines can be stopped suddenly from full speed with heavy fires on without any consequent difficulty as to sudden rise in steam pressure, and, on the other hand, the steam pressure can be raised 100 pounds in a few minutes, yet it has never happened that leakage at any tube or joint has appeared. The boiler is not liable to priming, and the water surface is not disturbed or the heating surface uncovered by the rolling of the boat.

"Besides these advantages with regard to the general working and management on cruise, the tubulous boiler possesses other important advantages.

"Thus it is well adapted to high pressure; the boiler having no flat surfaces, stays can be done away with. The combined weight of the boiler proper with its content of water is considerably less than is the case with the locomotive boiler.

"Considered as a war-ship, the advantages which a torpedo-boat with two tubulous boilers, each able to drive the boat at a high speed, possesses over a similar boat fitted with one large locomotive boiler are evident. Having a large and very effective heating surface, the boiler is very economical as to coal consumption; nearly all the heat developed by combustion is given off by the gases before they enter the funnel, and no unburned coal escapes from the funnel, which point speaks largely in favor of this boiler for torpedo-boats' purposes. Our engineers are, in fact, so satisfied of their superiority over the locomotive boiler that we, without hesitation, fit these boilers in all new boats, and when locomotive boilers in older boats have to be taken out for repairs, we replace them with the tubulous boiler, as now done in the *Delfinen.*"

The French twin-screw torpedo-boat *Coureur* is fitted with two Thornycroft boilers, one for each engine. Her trial at Cherbourg on the 26th of August, 1888, one engine and one boiler only in use, the other screw revolving freely, gave the following results:

Time of trial	6 hours.
Kind of coal used	Nixon's navigation.
Total of coal used	990 lbs.
Mean speed	9.948 knots.
Mean I. H. P	105.36.
Pounds. coal per I. H. P. per hour	1.566.
I. H. P. at 10 knots speed	105.36.
Consumption of coal for 1,000 knot at 10 knots speed	7.36 tons.

This consumption of coal, 1.566 pounds per I. H. P. per hour, was obtained with a compound engine. With triple expansion better results might have been expected.

It is well to note here that the I. H. P., in the expression "pounds coal per I. H. P. per hour," is always in these experiments the horse-power of the main engines alone, the horse-power of the auxiliaries not being taken into consideration at all.

Admiral Krantz, Minister of Marine, writes in reference to the *Coureur:*

"I am pleased to acknowledge that, from the reports which have come to me, the *Coureur* appears to have given every satisfaction in respect to her sea-going qualities during her voyage from Cherbourg to Toulon. The working of her evaporative apparatus has been equally most satisfactory, notwithstanding that the utilization of the fuel may not have been maintained to the same advantage as it had been on the trials."

We come now to the boats built by the Messrs. Thornycroft for the Government of India.

"The dimensions of these vessels are: Length, 134 feet 7 inches; beam, 14 feet 9 inches; and draught of water, 7 feet 1 inch.

"The stipulated speed was 21 knots on a run of two hours' duration with a load of 20 tons on board.

"On trial, the first boat, with a comparatively untrained crew, attained a speed of only 21.94 knots, while the second and third, with trained crews, attained speeds of 23.15 and 23.25 knots, respectively.

"These results are interesting as illustrating the fact that, no matter how we may improve our mechanism, the result obtained is controlled by the human element which manages it, "The displacement of these vessels was a little over 96 tons, and the I. H. P. 1,262, giving a displacement coefficient of 207.

"The metacentric height was stipulated to be between 1.2 and 2 feet, and was found on trial to be 1.6 feet upon conditions of tendering, and 1.55 feet when loaded for the voyage to India.

"With a view to determine the evaporative efficiency of the tubulous boilers with which these vessels were fitted, a careful experiment was conducted with the concurrence of the India Office on the advice of the Admiralty by Professor Kennedy, of the University College, on one of the boilers of the last of these three vessels, the principal results being that with natural draft."

The results are contained in the following table:

Air pressure in inches.	I. H. P.	Pounds of water evaporated per pound of coal.	Pounds of coal per I. H. P. per hour.	Temperature of chimney gases in degrees Fahrenheit.
0	89	13.40	2.28	421
0.27	282	12.48	1.98	...
0.49	449	12.00	1.99	....
2.00	*775	10.29	2.26	777

*Highest attainable.

"The coal consumption on these experiments seems high, but it will readily be understood that as the horse-power of the main engines only was used in the calculation, and no account whatever taken of the auxiliary engines, all of which, especially the donkey, were very extravagant in their use of steam, the result is very small in deed.

"The evaporative value of the coal was found by calculation from its chemical constituents to be equal to 15.41 lbs. of water per lb. of coal from and at 212 degrees F., and this was corroborated by a calorimetric experiment, the result of which differed only by about 1 per cent. from the calculated result.

"The efficiency of the boiler with natural draft was therefore $\frac{13.4}{15.4}$, or 87 per cent. of the theoretical evaporation, a result concerning which Professor Kennedy says:

"'It is only right that I should say that this is the highest boiler efficiency I have ever found upon any trial with which I have had to do, if indeed it is not, as I almost think it is, the highest on record in any trustworthy manner.'

"In summing up the result of all the trials, Professor Kennedy says further:

"'I have already remarked on the most notable evaporative efficiency of Mr. Thornycroft's boiler when working at very low pressure.

"'The manner in which it retains that high efficiency when doing seven times as much work is perhaps equally remarkable.

"'That one and the same boiler should be able to supply steam for powers varying from 90 to 270, maintaining so high an average efficiency throughout the whole range, is a most remarkable result, and on which you may fairly be congratulated.'

"I may add that the weight of the boiler experimented on, with all its fittings, mountings, water-pipes, donkey, spare gear, and funnel, was only 11.3 tons, which gives 68 I. H. P. per ton of boiler, and compares favorably with the locomotive boiler of about the same power in a torpedo-boat which only gives 48 I. H. P. per ton, or the same type of boiler in use in the later English torpedo-catchers, which is still worse, only giving 43 I. H. P per ton.

"These facts speak for themselves as to the advantage to be derived from the use of our boiler in the latter classes of vessel, and I may say that we have been invited by our own and several foreign Governments to submit proposals for boilers ranging from 3,200 to 6,300 I. H. P."

The foregoing would indicate that, for large powers, the Messrs. Thornycroft intend working their tubulous boiler in battery.

THE COWLES WATER-TUBE BOILER.

The demand for increased steam pressure, less weight, and large and rapid evaporative power in boilers has brought out several new designs, among which is the Cowles water-tube boiler.

From the accompanying sketch and the following brief description its action may be readily understood:

The boiler consists of a rectangular grate and ash-pan, over which is set horizontally a cylindrical shell for steam and water; from the back part of this shell a steam drum projects back horizontally; from its bottom large "water-leg" tubes extend down to one or more water-drums lying horizontally back of the furnace and below or at its level; numerous bent water-tubes, with ends expanded in, extend vertically and connect the water and steam drums, and the whole is incased in a suitable casing.

At first sight this boiler appears very like the Thornycroft tubulous boiler, but on examination many points of difference present themselves. In the Thornycroft boiler the three cylinders are of equal length, while in the Cowles the water-drums are only as long as the steam-drum at the rear of the upper cylinder. In the Thornycroft boiler the down-cast pipes are outside the boiler, while in the Cowles they are in the hottest part of the fire. In the Thornycroft the water-tubes all enter the upper cylinder above a horizontal diameter, and the steam and water then strike a baffle-plate and separation ensues, while in the Cowles the water-tubes enter the steam-drum around its whole circumference, separation taking place by gravity alone from those tubes which discharge above the water level. The most radical difference, however, is in the crown of the furnace. In the Thornycroft the tubes of the inner row are so bent as to form the crown of the furnace and protect the bottom of the upper cylinder from the fire. So important is this considered that an additional protection in the form of an asbestos baffle is fitted to the under side of the upper cylinder. In the Cowles the under side of the upper cylinder acts as the furnace-crown, making the upper cylinder a steam generator.

Mr. Cowles claims the following advantages for his boiler:

Great safety, unexcelled steaming capacity, and a steady steam pressure and water level with natural draft, or when forced hard and using either fresh or salt water.

Unequaled lightness and compactness.

Exceptional durability and capacity for withstanding hard and careless use and high forcing.

The greatest possible economy either with natural or forced draft.

Unequaled accessibility for cleaning, inspection, and repairs.

Simplicity of construction.

The Cowles boiler is in use in the following boats: Steam-launch *Ellie*, New York; steam-launch *Daphne*, Mamaroneck, N. Y.; fire-boat *Engine 31*, Boston, Mass.; fire-boat *Wm. F. Havemeyer*, New York.

Boilers are now under construction for the new iron propeller for the supervisor of the port, New York, and for the new propeller for the New York State quarantine commission.

In a report to the Chief of the Bureau of Steam-Engineering, Navy Department, Chief Engineer Charles H. Loring, U. S. Navy, president of the Experimental Board at the New York navy-yard, says:

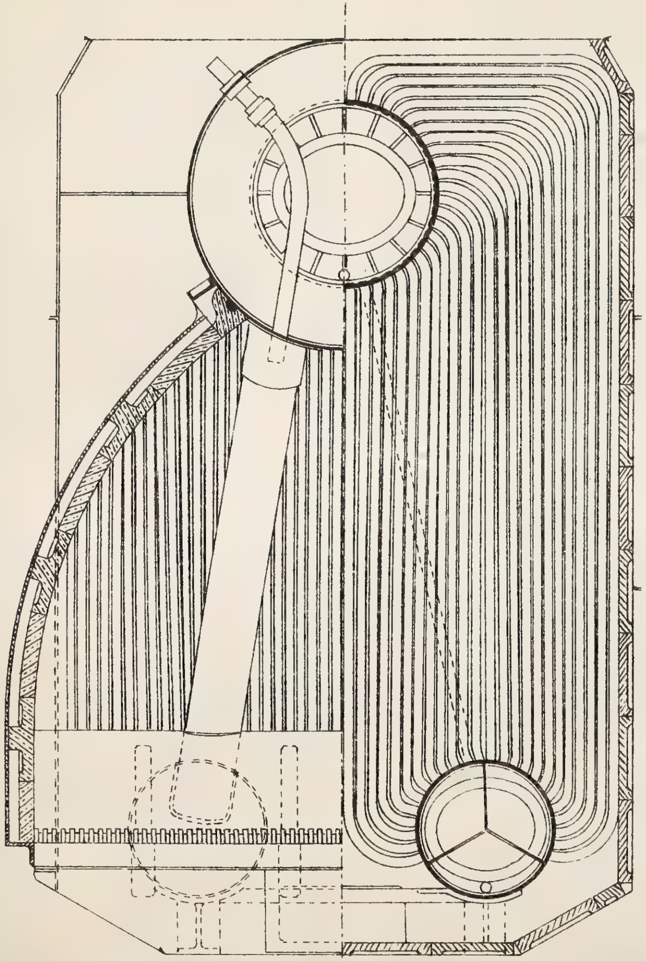
"It would be hasty and unwise to form any decided opinion of the efficiency of this type of boiler from the observations it was possible to make during that trial, but

Total Heating Surface	1920 sq.ft.
" Grate "	484 "
Steam space to mean water	81 cu. "
Water " " "	67.2 "
Working Pressure	200 lbs.

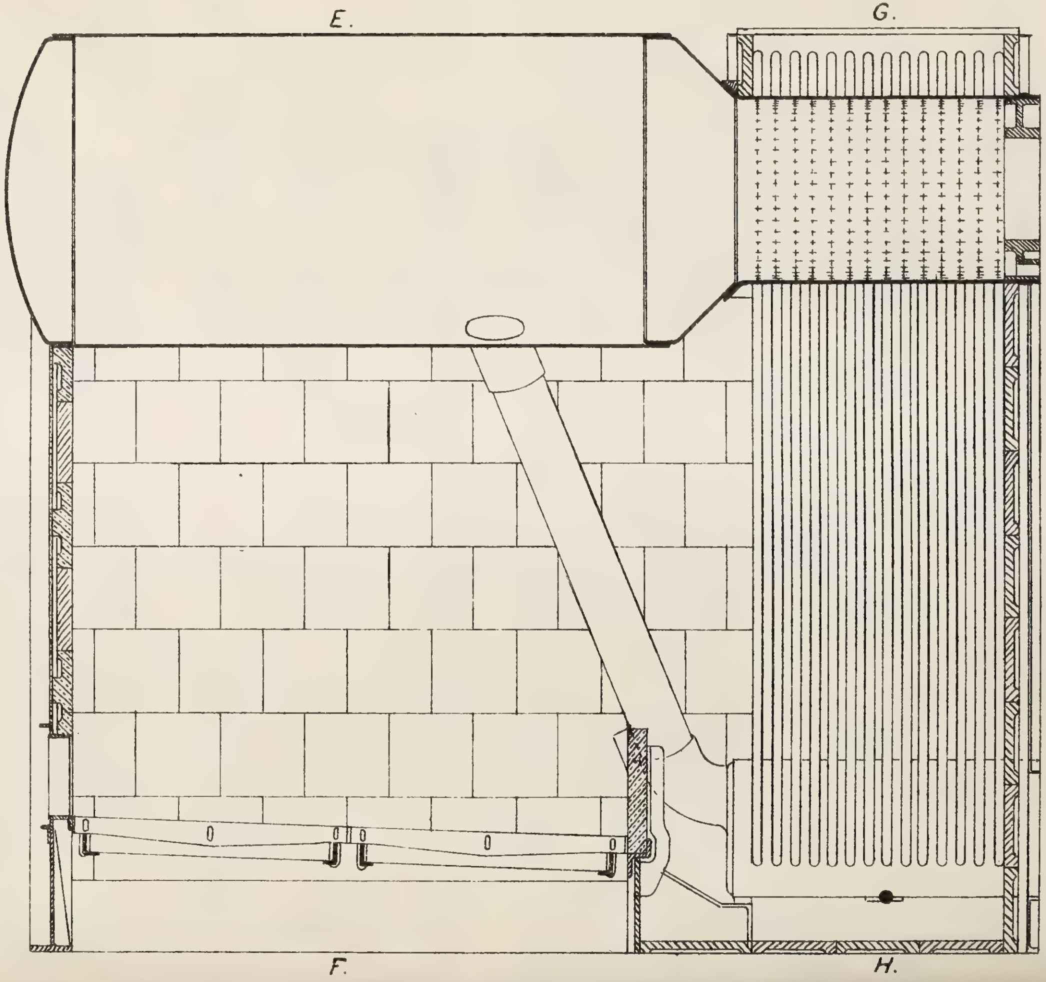
Cowles Water-tube Boiler.

Standard Size K. Marine.

Weight complete, empty	8.5 Tons
" steaming, tubes full	10.375 "
" per sq.ft. H. S. empty	9.9 lbs.
" " " steaming	12.1 "



Section EF. Section GH.



Longitudinal Section.

my impressions of it are very favorable, quite strong enough to assure the Bureau that it may reasonably be expected to develop good qualities in a competitive test."

FEED-WATER HEATERS.

Heating the feed-water for boilers is an old idea and was in use many years ago. It does not appear to have met with much success, and was finally abandoned. There were different methods employed to effect this heating, most of which depended upon the utilization of heat that otherwise would have been wasted, such as the heat in the chimney gases, the heat in the water blown out of the boiler, and the heat in the exhaust steam on its way to the condenser.

The objection to the use of the chimney gases is that any reduction of their temperature affects the draft. This, however, would not be the case with an artificial draft.

When salt water was universally used in marine boilers, it was customary to blow out a portion of it, either at stated periods or continuously, in order to keep down its concentration. This water blown off necessarily carried away with it a large quantity of heat, and a portion of this heat was recovered and returned to the boiler by making the water blown off and on its way to the sea surround the feed-water on its way to the boiler. One advantage claimed for this method was that the heating took place after the water had passed the feed-pump, whose action was therefore unaffected thereby. By the use of distilled water in boilers this device becomes impossible.

The difference in the temperatures of the exhaust steam and of the hot-well is so small that any device looking towards the heating of the feed-water from this source becomes so cumbersome that any small gain is more than counterbalanced by the mechanical disadvantages.

Since the introduction of triple and quadruple expansion engines and pressures in the hundreds, feed-water heaters have again been introduced, and with an appreciable gain in economy, if we may rely on the statements of those using them.

Leaving aside the question of economy, however, feed-water heaters possess another advantage which alone would warrant their use at the present time, and that is the reduction of the range of temperature in the boiler and the consequent tendency to unequal expansion and contraction, by which great strains are thrown on the material of the boiler. In addition to the above, feed-water heaters are so arranged as to abstract the contained air and fatty matter and send the water to the boiler practically pure. This deposition of the impurities of the feed-water in the heater, from which they are readily removed, is of great advantage, as the heating surfaces of the boiler are thereby kept clean and in their most efficient condition.

In addition to the sources of heat previously mentioned, steam has been taken from one of the intermediate reservoirs and also directly from the boiler. In the Weir system steam is drawn from the intermediate reservoir, and the saving is found to be 8 per cent.; but 4 per cent. is lost by not working the steam so drawn off through the low-pressure cylinder. In the Kirkaldy system the steam is drawn directly from the main boilers and enters a system of tubes, inclosed in a cylindrical casing, at the top. The feed-water is pumped into this casing at the bottom, surrounds the tubes containing the boiler steam, has its temperature raised by the abstraction of heat from and consequent condensation of the steam, and passes out at the top of the casing to the boiler. The condensed steam is drawn off at the bottom of the heater and enters the hot-well below the water level. The heater is fitted with a door by which the deposited impurities may easily be removed.

This device is fitted to many steamers in the British merchant marine, and in every case a gain in economy is reported. It is especially noteworthy that in most every instance stress is laid upon the fact that a uniform steam pressure is more easily maintained, particularly while cleaning fires.

As the steam in this case is taken from the boiler, any gain in economy must come from the method of application of the heat, as there can certainly be no more heat generated by the combustion of the coal with the heater than without it.

Among the statements received from British steamers fitted with feed-water heaters are the following:

S. S. (*a*) { Temperature of feed raised from 128° to 192°.
Saving in coal per day, 1.2 tons.

S. S. (*b*)—Saving in coal per day, 1 ton.

S. S. (*c*) { Temperature of feed raised from 130° to 215°.
Saving in coal per day, 5 cwt.

S. S. (*d*) { Temperature of feed raised from 130° to 195°.
Saving in coal per day, 15 cwt.

S. S. (*e*) { Temperature of feed raised from 126° to 200°.
Saving in coal per day, 2.3 tons.

S. S. (*f*) { Temperature of feed raised from 130° to 211°.
Saving in coal per day, 1.05 tons.

S. S. (*g*) { Temperature of feed raised from 138°–140° to 200°–210°.
Saving in coal per day, 1 ton.

Other examples might be cited, but the foregoing are deemed sufficient to show the advantages claimed by the use of feed-water heaters.

C. W. Rae,
Passed Assistant Engineer, U. S. N.

ORDNANCE.

The items of chief interest in the past year's record of progress are the experimental tests of various high explosives for bursting charges of shell and the development of slow-burning powders. No new heavy guns have appeared, and there seems to be a growing impression that the limit in the direction of weight and calibre has already been attained; in fact, it has been questioned if the useful limit has not been exceeded, for naval guns, at least. The heaviest gun now contemplated for vessels of most recent design is one of about 68 tons weight and 13.5-inch calibre. No new trials of rapid-fire guns of large calibre have been recorded, and it would seem that with the 6-inch gun the benefit to be derived from the application of the peculiar features of the rapid-fire system has also reached a limit.

There is some difficulty in arriving at just how much has been accomplished with high-explosive projectiles, in consequence of the secrecy observed in conducting the experiments and the care with which the results are guarded. Especially is this the case with melinite shell, and the reports of the results of experiments with these on p. 420 must be considered as having no higher authority than accounts by professional men who probably were not eye-witnesses of what they describe.

The notes on Walsrode gun-cotton shell (p. 420) are interesting as showing that the successful use of wet gun-cotton charges for shell is an accomplished fact; they would be more interesting still if they contained a description of the exact method of accomplishment, but this, of course, is not given.

Pages 415 to 417 contain an abstract of Krupp's report, No. 73, on the Rhenish-Westphalia P.P.C./86, a new slow-burning powder; also, several press notices of smokeless small-arm powders.

Other matters of interest are the trials of the 15-inch pneumatic dynamite gun (p. 386) and the Pittsburg and Thurlow guns (p. 393).

PROGRESS AT HOME.

The plant of the Pratt and Whitney Company for the manufacture of Hotchkiss R. F. guns and revolving cannon is now in complete running order. Until recently the deliveries of forgings by Midvale had been considerably delayed, and the progress made with the guns has been retarded in consequence; but the amount of material now on hand is sufficient to permit the work to advance steadily and economically.

The status of the order placed with the Pratt and Whitney Company by the Hotchkiss Ordnance Company was as follows on July 1st: Guns delivered, thirteen 37^{mm} R. C., ten 1-pounder R. F., five 3-pounder R. F.; in hands of finisher, nineteen 37^{mm}, eight 3-pounders to be delivered within six weeks, seven 6-pounders.

The Winchester Arms Company, of New Haven, has made good progress with the ammunition of the above guns, so far as its own work is concerned, but delays have occurred through the failure to supply powder as rapidly as required. Up to July 1st there had been delivered 22,200 rounds of 37^{mm} shell, and 2,100 rounds of 3-pounder common shell.

The cartridge-cases are drawn from discs of brass, and are of very fine make. The castings for cast-iron projectiles are supplied by outside parties, but are machined and tested by the company. The steel projectiles are made from bar steel furnished by Park Brothers, of Pittsburg. The bars are cut into proper lengths, forged to shape, and then tempered and machined.

The batteries of the *Yorktown, Petrel, Concord,* and *Charleston* are complete.

The estimated dates of final deliveries of forgings and of the completion of guns designed for the *Bennington, Baltimore, Miantonomoh, Philadelphia, Newark,* and *San Francisco* extend throughout 1889 and 1890.

A contract was concluded September 5, 1888, between the Department and the West Point Foundry Company, under which the latter is to machine-finish and construct six 6-inch B. L. R., mark III; the first gun to be delivered within six months and the last one within eleven months after the receipt of the material, complete, for one gun.

A like contract was concluded on the same day with the South Boston Iron Works.

The act of Congress of September 7, 1888, contains the following provisions of special interest to the service: For modern guns and ammunition for instructing the cadets of the Naval Academy, $55,000; for same for instructing the apprentices of the training squadron, $50,000; also, a sum (not stated) for prizes to enlisted men for excellence in ordnance exercises and target firing.

ARMY GUN FORGINGS.

The act of Congress of September 22, 1888, appropriates the sum of $1,500,000 for the purchase of rough-finished steel forgings for high-power coast-defense guns of 8-, 10-, and 12-inch calibre.

The leading specifications governing the manufacture and inspection of steel for these forgings are included in the following extract from the general specifications prescribed by the Ordnance Department, U. S. Army, in 1888:

Tubes and jackets.

Ingots for tubes shall have an area of cross-section in that part of the ingot used for the tube forging at least four times as great as the maximum area of cross-section of the rough forging, except that for tubes for cannon of 12-inch calibre and upward the area of cross-section of that part of the ingot used for the tube forging shall be at least three and one-half times as great as the maximum area of cross-section of the rough forging; the ingots for jackets shall have an area of cross-section in that part of the ingot used for the jacket forging at least three and one-half times as great as the maximum area of cross-section of the rough forging, except that for jackets for cannon of 12-inch calibre and upward the area of cross-section of that part of the ingot used for the jacket forging shall be at least three times as great as the maximum area of cross-section of the rough forging; and the ingots for lining tubes shall have an area of cross-section in that part of the ingot used for the lining-tube forging at least six times as great as the maximum area of cross-section of the rough forging. If bored ingots are used, then the wall of the ingot shall be reduced by forging at least as much as to one-half of its original thickness.

Only so much of any ingot shall be used for tubes and jackets as shall remain after at least six per centum of the total weight of the ingot has been cut from the bottom of the ingot, and at least thirty per centum from the top.

Tubes and jackets shall, if desired, be annealed at a high heat either after forging or after rough finishing, and before oil-tempering. This heat will be at least as high as that at which the pieces are subsequently to be heated for oil-tempering.

The pieces shall, after rough-boring and turning, be oil-tempered, and subsequently annealed or tempered at a lower temperature than that of the previous operation.

The stem of all test specimens shall, if possible, be taken within the finished interior and exterior surfaces of the piece prolonged.

Tangential test specimens shall be furnished from each tube and jacket as specified in the following—

Table 1:

Calibre of cannon.	Designation of piece.	Kind of test specimen.	Number of specimens from—		Size of specimens.		Minimum distance of axis from end of forging.
			Breech end.	Muzzle end.	Length of stem.	Diameter of stem.	
					Inches.	*Inches.*	*Inches.*
Field-cannon of all calibres.	Tube	Tensile	2	2	2. 0	0. 505	1. 15
	Jacket	do	2	or 2	2. 0	0. 505	1. 15
Siege-cannon of all calibres.	Tube	do	2	2	3. 0	0. 564	1. 25
	Jacket	do	3	3	3. 0	0. 564	1. 25
Sea-coast cannon of 8-inch calibre and upward to 12-inch calibre.	Tube	do	3	3	3. 0	0. 564	1. 50
	Jacket	do	4	4	3. 0	0. 564	1. 50
Sea-coast cannon of 12-inch calibre and over.	Tube	do	4	4	3. 0	0. 564	1. 50
	Jacket	do	4	4	3. 0	0. 564	1. 50

All with screw-ends as required.

Each of the test specimens should show the physical qualities given in the following—

Table 2:

Calibre of cannon.	Designation of piece.	Elastic limit.	Tensile strength.	Elongation after rupture.
		Lbs. per sq. inch.	*Lbs. per sq. inch.*	*Per cent.*
Field-cannon of all calibres	Tube	46, 000	86, 000	22. 0
	Jacket	50, 000	93, 000	19. 0
Siege-cannon of all calibres	Tube	46, 000	86, 000	20. 0
	Jacket	50, 000	93, 000	18. 0
Sea-coast cannon of 8-inch calibre	Tube	46, 000	86, 000	19. 0
	Jacket	50, 000	93, 000	17. 0
Sea-coast cannon of 10-inch calibre and over	Tube	46, 000	86, 000	19. 0
	Jacket	48, 000	90, 000	17. 0

The forgings shall, however, be accepted as to physical qualities provided no one of the specimens shows results in any particular below the figures given in the following table:

Table 3.

Calibre of cannon.	Designation of piece.	Elastic limit.	Tensile strength.	Elongation after rupture.	Contraction of area.
		Lbs. per sq. inch.	*Lbs. per sq. inch.*	*Per cent.*	*Per cent.*
Field-cannon of all calibres	Tube	42,000	78,000	20.0	35.0
	Jacket	46,000	86,000	17.0	30.0
Siege-cannon of all calibres	Tube	42,000	78,000	18.0	30.0
	Jacket	46,000	86,000	16.0	27.0
Sea-coast cannon of 8-inch calibre	Tube	42,000	78,000	17.0	30.0
	Jacket	46,000	85,000	16.0	27.0
Sea-coast cannon of 10-inch calibre and over.	Tube	42,000	78,000	17.0	30.0
	Jacket	44,000	83,000	16.0	27.0

Except that for the calibres and pieces enumerated below, one, and only one, specimen from each end may be in any one particular lower in its qualities than the figures given in Table 3, but must not be, in that particular, lower than the figures in the following table:

Table 4.

Calibre of cannon.	Designation of piece.	Elastic limit.	Tensile strength.	Elongation after rupture.	Contraction of area.
		Lbs. per. sq. inch.	*Lbs. per sq. inch.*	*Per cent.*	*Per cent.*
Sea-coast cannon of 8-inch calibre	Jacket	44,000	83,000	14.0	22.0
Sea-coast cannon of 10-inch calibre and over.	Tube	40,000	75,000	15.0	25.0
	Jacket	42,000	80,000	13.5	20.0

In addition to the tensile tests prescribed, the tubes and jackets shall be submitted to a powder test, or percussive hydraulic test if desired by the United States, with an interior pressure a little (about 1,000 pounds) less than their elastic resistance. No weakness or defect should be developed by these tests; and the manufacturers shall detach rings for mandril or initial tension tests when in special cases they are notified that such rings are desired.

Hoops.

Only so much of any ingot shall be used for hoops as shall remain after at least 5 per centum of the total weight of the ingot has been cut from the bottom of the ingot, and at least 28 per centum from the top.

Cylindrical hoops may be either forged or rolled, but will be rolled whenever practicable.

The specifications governing the treatment of hoops are practically the same as those governing the treatment of tubes and jackets.

Tangential test specimens shall be furnished from each trunnion hoop, as specified in the following table:

Table 5.

Calibre of cannon.	Number of test specimens.		Size of specimens.		Minimum distance of axis from end of hoop.
	Breech end.	Muzzle end.	Length of stem.	Diameter of stem.	
			Inches.	*Inches.*	*Inches.*
Field-cannon of all calibres	2	or 2	2. 0	0. 505	1. 15
Siege-cannon of all calibres	3	or 3	3. 0	0. 564	1. 25
Sea-coast guns of 8-inch calibre and over	4	or 4	4. 0	0. 564	1. 25
Mortars of 8-inch calibre and over	3	or 3	4. 0	6. 564	1. 25

All with screw-ends as required.

Tangential test specimens shall be furnished from cylindrical hoops, as specified in the following table:

Table 6.

Rough-finished size of hoops.	Number of test specimens.			Size of specimens.		Minimum distance of axis from end of hoop.
	From breech end.	From muzzle end.	From hoop.	Length of stem.	Diameter of stem.	
				Inches.	*Inches.*	*Inches.*
Not more than 8 inches inside diameter. Not more than 30 inches long	....	....	1	2. 0	0. 505	1. 15
Not more than 8 inches inside diameter. More than 30 inches long	1	1	....	2. 0	0. 505	1. 15
More than 8 inches inside diameter. Not more than 16 inches inside diameter. Not more than 30 inches long	....	....	2	3. 0	0. 564	1. 25
More than 8 inches inside diameter. Not more than 16 inches inside diameter. More than 30 inches long	2	2	....	3. 0	0. 564	1. 25
More than 16 inches inside diameter. Not more than 34 inches inside diameter. Not more than 26 inches long	....	....	3	4. 0	0. 564	1. 25
More than 16 inches inside diameter. Not more than 34 inches inside diameter. More than 26 inches long	3	3	....	4. 0	0. 564	1. 25
More than 34 inches inside diameter. Not more than 25 inches long	....	....	4	4. 0	0. 564	1. 25
More than 34 inches inside diameter. More than 25 inches long	4	4	....	4. 0	0. 564	1. 25

All with screw-ends as required.

The test specimens should show the mean physical qualities given in the following table, as a minimum:

Table 7.

FOR TRUNNION HOOPS.

Size of specimens.		Elastic limit.	Tensile strength.	Elongation after rupture.
Length of stem.	Diameter of stem.			
Inches.	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Per cent.*
2.0	0.505	50,000	90,000	18.0
3.0	0.564	50,000	90,000	15.0
4.0	0.564	50,000	90,000	13.0

FOR CYLINDRICAL HOOPS.

2.0	0.505	50,000	90,000	18.0
3.0	0.564	53,000	93,000	15.0
4.0	0.564	53,000	93,000	13.0

Provided that for trunnion hoops, one specimen may be, in any one particular, below the figures given in Table 7, but not lower than 48,000 pounds per square inch in elastic limit, 88,000 pounds per square inch in tensile strength, or 1 per cent. less than given in elongation after rupture; and provided, further, that for cylindrical hoops, when three or four specimens are taken, one of these specimens, or one from each end, and no more, may be, in any one particular, below the figures given in Table 7, but not lower than 50,000 pounds per square inch in elastic limit, 90,000 pounds per square inch in tensile strength, or 12 per cent. in elongation after rupture.

Parts of breech mechanism.

Only so much of any ingot shall be used for breech mechanism forgings as shall remain after at least 5 per cent. of the total weight of the ingot has been cut from the bottom of the ingot, and at least 28 per cent. from the top.

The treatment specified for parts of breech mechanism is practically the same as that for tubes and jackets.

The test specimens must show the physical qualities given in the following table, as a minimum:

Table 8.

Name of part.	Size of specimen.		Elastic limit.	Tensile strength.	Elongation after rupture.
	Length of stem.	Diameter of stem.			
	Inches.	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Per cent.*
Breech-block, spindles, hinge-pins, and rollers.	2.0	0.505	46,000	86,000	18.0
	3.0	0.564	46,000	86,000	16.0
Lever handles, breech plates, face plates, block-carriers, and nuts.	2.0	0.505	40,000	75,000	20.0
	3.0	0.564	40,000	75,000	18.0
Gas-check cups, gas-check rings, and bars for securing pins.	2.0	0.505	70,000	125,000	12.0
	3.0	0.564	70,000	125,000	10.0

Under authority of the act before quoted, the War Department has contracted with the Bethlehem Iron Company for 23 sets of steel forgings for 8-inch B. L. R., 23 for 10-inch, 15 for 12-inch.

The Bethlehem plant was established, it will be remembered, as a result of liberal contracts with the Navy Department, which should in a measure compensate the company for the vast outlay of money necessary to the installation of a first-class gun-forgings plant; as a consequence of this far-sighted policy on the part of the Navy Department, the Army was enabled to place its contract within three months after the appropriation became available.

ARMY GUNS SUBMITTED BY PRIVATE PARTIES.

The act of September 22, 1888, also appropriates $250,000 for the purchase of material for, and the manufacture of, 12-inch cast-iron steel-hooped B. L. mortars.

Section 1 of the same act creates a Board of Ordnance and Fortification, and section 6 provides that the said Board shall prescribe the dimensions and method of testing guns that may be submitted by private parties, and that if any gun offered shall fulfill the requirements of the Board, then the gun and ammunition shall be paid for at a fair valuation, and contract shall be made at a reasonable price with the party presenting the best of such guns as follows: For not less than fifty 10-inch steel guns; for not less than fifty 12-inch steel guns; for not less than fifty and not more than one hundred 12-inch cast-iron steel-hooped B. L. mortars. The Government is limited to a total expenditure of $6,500,000. All guns and material purchased must be of domestic manufacture.

The Board has formulated the following conditions, which have been approved by the Secretary of War:

"The 10-inch gun shall be about 30 tons in weight, the length 34 calibres, measured from the face of the obturator to the face of the muzzle. It is desirable that the trunnions be 12 inches in diameter and the distance between rim bases 42 inches, in order to avoid the necessity for a special carriage. The power must be a muzzle energy of not less than 15,000 foot-tons; the range shall, for 20 degrees elevation, be 13,650 yards, and corresponding ranges shall be obtained with lower elevations. The requirements as to accuracy are that 25 per cent. of the shots shall strike within a vertical rectangle 1.4 feet by 1 foot at 1,500 yards' range, and within a horizontal rectangle 48.5 yards by 9.2 yards at 10,000 yards' range.

"The endurance test should not be less than 300 rounds with full charges. After 250 or more rounds may have been fired, the gun may be lined wholly or in part, when at least 50 rounds more will be fired to fully test the strength of the construction. After this the general soundness and efficiency of the gun should not be materially impaired, except so far as may have resulted from erosion. Should any material modification of the construction be made during the trial, at least 50 rounds, with full charges, shall be fired thereafter. The weight of projectile to be used with the full charge shall be about 575 pounds. Three hundred rounds of ammunition shall be the 'proper' amount to be supplied with the gun for test.

"As a proof of general efficiency, the breech mechanism should work freely and be convenient for operating, the opening and closing of the breech to be performed without great difficulty by one man. The projectiles shall admit of being readily handled, inserted, and centred in the bore, and not be subject to injury or deformation either in handling or transportation. A rapidity of fire of 15 rounds per hour shall be attainable, using such appliances for loading as are employed by the Ordnance Department, U. S. Army. The repairs allowable during the entire trial of a gun, exclusive of the insertion of a lining tube, will be confined to repairing or renewing parts injured during trial. No alterations that may affect the general construction of any part will be made without the sanction of the Board.

"For the 12-inch gun the weight is to be about 52 tons, the bore 34 calibres long, and it is desired that the trunnions be 14.5 inches in diameter and 49.8 inches between rim bases. The power is to be not less than 26,000 foot-tons, the range 14,700 yards at 20 degrees elevation; the accuracy the same as the 10-inch gun; endurance not less than 250 rounds (a lining may be inserted after 200 rounds); the weight of projectile about 1,000 pounds; and the other conditions are to be the same as in the case of the 10-inch gun, except that a fire of 10 rounds per hour shall be attainable.

"The experimental guns should be submitted for test as soon as practicable and within three years from date.

"It is not considered practicable for the Board to determine at this time what will be a 'fair valuation' of an experimental gun which shall have fulfilled the requirements prescribed, nor what price would be 'reasonable' for a further supply of similar guns. It is believed to be better on all accounts to leave these questions for determination after the actual cost and value of such guns can be known, it being understood as the duty of the Board to act in such matters with entire impartiality as between the United States and any party who shall attempt to supply the desired guns. It is understood, however, that the Board is disposed to deal in a liberal spirit with parties submitting guns, with a view to carrying out the evident purpose of the act of Congress, which was to encourage the development in the United States of works capable of supplying the needs of the country in the way of sea-coast and other kindred defenses."

PNEUMATIC DYNAMITE GUNS.

The Pneumatic Dynamite Gun Company is under contract to manufacture for the War Department seven dynamite guns, with ammunition, machinery, etc., complete, at a total cost of $395,000. The guns are to be delivered and mounted ready for service by November 6, 1889. They are to be distributed as follows: One 8-inch and two 15-inch at Sandy Hook; two 15-inch at Fort Schuyler, N. Y.; two 15-inch at Fort Warren, Boston.

The act of Congress of March 2, 1889, appropriates $87,500 for the purchase of three additional 15-inch guns for the defense of the Pacific coast; and the contract for these has been made with the same company.

The contract prescribes that the 8-inch gun may be 70 calibres long. Of the 15-inch guns, one is to be 32 calibres long and the others 40 calibres. The time required to load and fire one shell containing 500 pounds of explosives must not exceed three minutes, and ten rounds must be fired within forty minutes. A shell containing 200 pounds of explosives must be fired in two minutes, and ten consecutive rounds in twenty-seven minutes; and for shell containing smaller charges one round in one and one-half minutes, and twenty consecutive rounds in ten minutes.

PROPOSED BREECH-LOADING TORPEDO HOWITZERS (EMMENS SYSTEM).

The act of Congress approved March 2, 1889, appropriates the sum of $15,000 to enable the Secretary of War to cause examinations and tests to be made in converting existing cast-iron ordnance of the War Department into steel-lined, breech-loading torpedo howitzers, for throwing high explosives according to the plans of Stephen H. Emmens, as set forth in his memorial to Congress of February 2, 1889.

According to the plan referred to the Rodman muzzle-loading gun is bored through the breech in continuation of the bore, and the rear portion is lined with a short steel tube. This tube is fitted on its interior with an interrupted screw-thread for the reception of the breech-plug, the construction of which constitutes the main feature of the converted gun and is as follows: A central cylinder extends through the plug, and around it are grouped cylindrical chambers of larger diameter, which extend from the front of the plug to some depth to the rear, but not entirely through it. These chambers contain the several powder-charges, and another charge is placed in the central cavity, which is closed in rear by a subsidiary breech-plug carrying the firing device.

The torpedo to be fired from the gun is an elongated shell charged with high explosive, and having a stud on its base, which fits in the central cavity of the main breech-plug. When the charge in the central cavity is fired a relatively weak impulse is communicated to the shell; then, as soon as the stud leaves the cavity, the heated gas inflames the charges in the surrounding chambers, which burn from front to rear, thus keeping the pressures at all times nearly uniform and well within the limits of safety.

If a still further nicety of adjustment be necessary, it may be obtained by providing studs of varying lengths to fit in the front ends of the powder-chambers on top of the charges, so that the latter may be discharged in succession. The studs are not necessarily attached to the base of the projectile.

According to the above plan the following would be the main features of a converted 15-inch Rodman:

Calibre	inches	15
Weight of gun	tons	25
Total length	inches	192
Powder-charge	pounds	115
Weight of large shell, carrying 534 pounds of high explosive	do	1,665
Weight of small shell, carrying 200 pounds of high explosive	do	734
Muzzle velocity:		
Large shell	foot-seconds	705
Small shell	do	1,063

The effective range of the gun is estimated at 3 miles, but, by reducing the calibre to 12 inches and rifling, it is thought probable that this figure could be considerably increased.

Mr. Emmens proposes to charge his torpedo shell with emmensite.

FOREIGN GUNS.

The number of guns required for the armament of the vessels proposed under the English programme, is as follows:

13.5-inch B. L	32 +	reserve	8
10-inch B. L	8 +	“	2
9.2-inch B. L	18 +	“	9
6-inch B. L	30 +	“	6
6-inch R. F	198 +	“	40
4.72-inch R. F	258 +	“	51
	544 +	“	116

The following return shows the number, description, place of manufacture, and actual cost of guns supplied by the War Department during the year 1887–’88:

Calibre and mark.		Place of manufacture.	Actual cost per gun.	Weight of gun.	Service.	
					Land.	Naval.
	Mark.			*Tons.*		
16.25-inch	I*	Elswick Ordnance Company	$93,159	111	......	2
13.5-inch	I	Royal Gun Factory	52,963	69	......	3
	II		51,111	67	......	2
12-inch	V		33,095	45	......	2
9.2-inch	I		12,389	22	....	4
	II		12,389	21	......	1
	IV		18,398	23	6	....
	V		16,815	22	......	1
	V	Elswick Ordnance Company	21,615	22	......	1

*Indicates Elswick Ordnance Company design; all others are of Royal Gun Factory design.

Calibre and mark.		Place of manufacture.	Actual cost per gun.	Weight of gun.	Service.	
					Land.	Naval.
	Mark.			*Tons.*		
8-inch	III	Elswick Ordnance Company	$10,268	14		4
	III	Royal Gun Factory	9,056	14		3
	IV	Elswick Ordnance Company	11,120	15		5
7-inch	I	Royal Gun Factory	9,432		1	
6-inch	IV		4,907	5		70
	IV		5,031	5	1	
	IV		4,910	5	7	
	IV	Elswick Ordnance Company	5,127	5		43
	IV	do	4,913	5	2	
	IV	Whitworth & Co	5,166	5		12
	V*	Elswick Ordnance Company	4,671	5	8	
				Cwt.		
5-inch	III	Royal Gun Factory	2,285	40		42
	IV		2,409			1
4-inch	IV		1,597	26		3
	V		1,813			3
12-pounder	I		999	7	13	
					38	202

The number of B. L. guns completed during the year ending December 31, 1888, is 160. Included in the number are—

	Guns.
16.25-inch	1
13.5-inch	6
12-inch	9
9.2-inch	6

The delays in furnishing guns already completed are attributed by the First Lord of the Admiralty to "the faulty principle which was adopted in the designs of these guns, viz, that of placing liners in the bores; these liners, when the guns were proved, cracked, and very considerable delay was caused before the guns were repaired and made efficient for issue to the fleet."

In the gun design now approved the feature which led to the failures above referred to has been eliminated.

The government has recently given an order to Messrs. Vickers & Co., of Sheffield, for twenty-one guns of 9.2, 10, and 12-inch calibre. This is the first time that Vickers & Co., or any other Sheffield firm has undertaken the production of finished ordnance.

The report of the "Jubilee round," quoted from *Engineer* in last year's publication, page 356, contains several misstatements: The firing was from the Woolwich 9.2-inch gun designed by General Maitland, *not* from the Elswick gun; the initial velocity was 2,375 foot-seconds, and the range slightly over 12 statute miles.

The Victoria government, Australia, has ordered a 15-inch pneumatic dynamite gun.

A paper on "Quick-Firing Guns for Fortress Defense," by Capt. F. G. Stone, R. A., contains a statement which we do not recall having seen in print before, and which is certainly instructive. The statement is quoted in full from Engineering:

"At Eastbourne a shell from one of these guns (6-pounder Hotchkiss) struck the chase of a 10.4-inch breech-loading gun and penetrated into the bore; at Shoeburyness a 9.2-inch breech-loading gun was struck on the chase, and a bulge of nearly one-half inch raised on the interior of the bore, thus rendering it unserviceable."

Grenfell Sights.

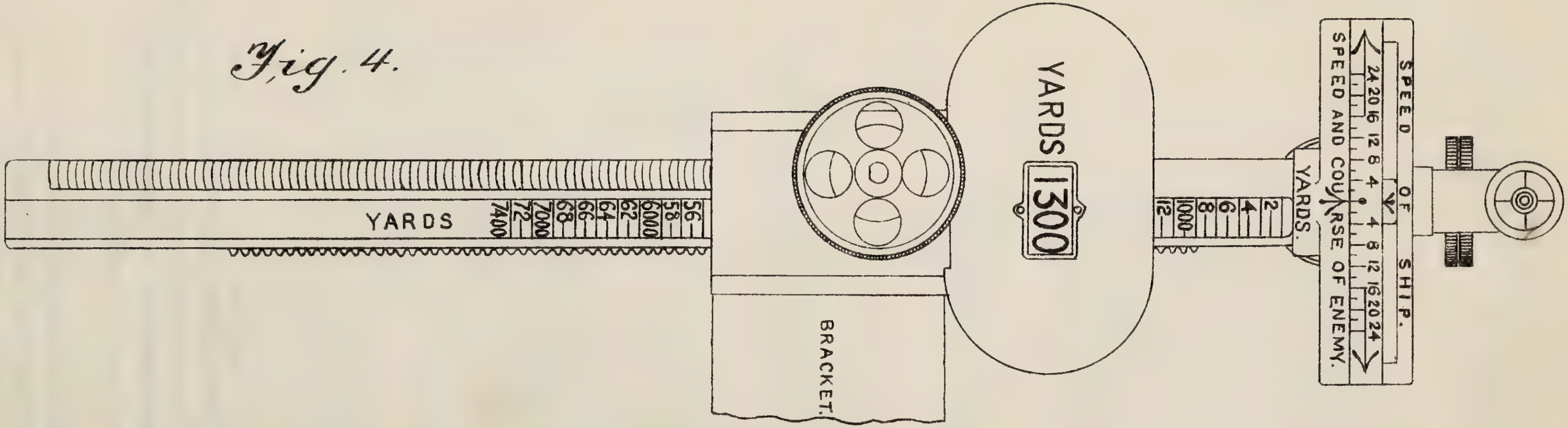


Fig. 4.

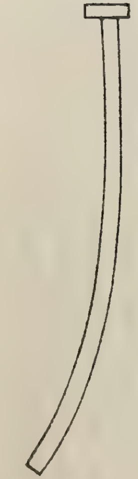


Fig. 3.

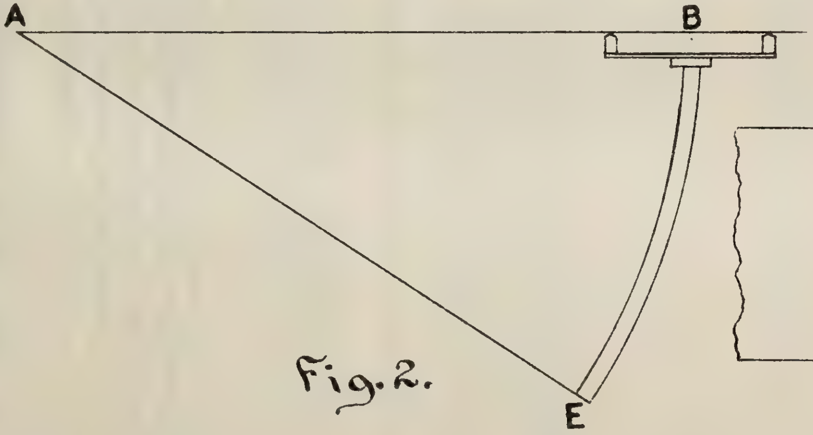


Fig. 2.

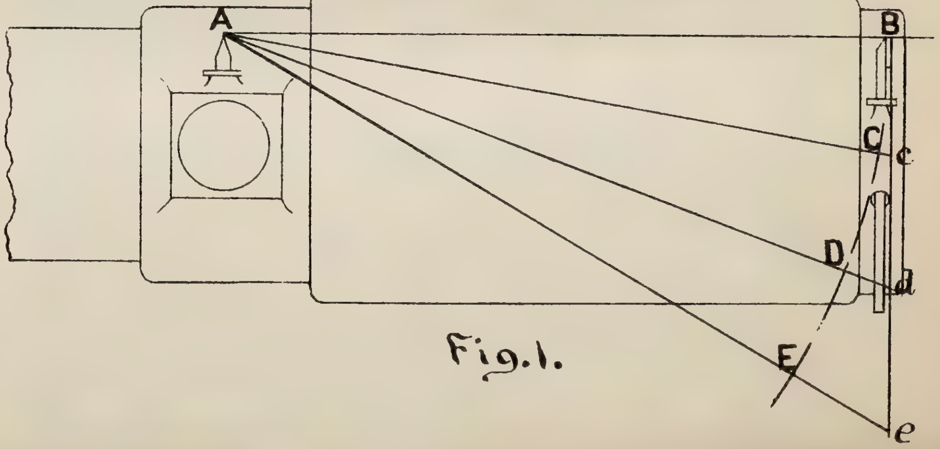


Fig. 1.

GRENFELL SIGHT.

Captain Grenfell, of the Elswick Ordnance Company, has invented an improved sight for great guns, the principle of which may be explained in a few words, as follows:

The usual method of sighting a gun is shown in Fig. 1, in which A is the front sight and B the head of the straight tangent bar. Now, if with A as a centre and AB as a radius, a portion of a circle be described, the arc will represent the movement of the head of the rear sight as the muzzle of the gun is elevated.

Take on this arc the points C, D, E, each representing, say, 5° of elevation; then the lengths of the arcs BC, CD, DE, will be equal. If the lines AC, AD, AE, be prolonged until they cut the vertical line which represents the sight bar, the lengths B*c*, *cd*, *de*, will give the necessary movement of the vertical bar to correspond with BC, CD, DE, and it will be seen that these lengths are no longer equal but continually increase.

It is clear that the fore sight A is an essential part of this method of sighting. It is also clear that if instead of a straight bar, B*e*, a curved bar, BE, be employed, and at the head of it are placed two pointers on a short horizontal bar, or a telescope, these pointers, or the axis of the telescope, will always be directed towards the point A, whatever be the movement of the curved bar. (Fig. 2.)

It is evident from this that the point A may be suppressed, whereby it will be possible to use, instead of the fixed radius AB, any other radius which may be more suitable, when the sight with its two pointers, or telescope, will still act as before. It is also evident that by the method of using an imaginary pivot it is possible to use the same radius for all guns, with this advantage: It results from the present system that in small guns this radius is very short, and consequently the subdivisions on the bar for degrees and yards are extremely minute and difficult to discern, and in the case of large guns, where the radius AB is of considerable length, they are unnecessarily large, and the total length of the bar is excessive. But by the use of a curved bar and an imaginary pivot, such a radius can be selected as will give, in all cases and with all guns, the length of subdivision, and consequently the total length of bar, most suitable for general use.

Captain Grenfell also proposes a bar having a varying curve such as that shown in Fig. 3. By adopting the proper nature of curve, slow at first, or for ranges at which the trajectory is flat, and increasing the curvature as the range increases and the path of the projectile becomes more curved, the subdivisions on the yard scale can be made of equal length throughout, whereby those near the top are increased from minuteness to easy visibility, and those near the bottom are reduced to convenient proportions.

Having equal movements for each equal and determined movement of distance, it becomes an easy matter to apply an indicator which shall record the range used in large figures. Fig. 4 shows such an indicator applied to the sight bar of a 4.72-inch R. F. gun.

RUSSIAN 6-INCH WIRE-WOUND GUN.

An experimental Russian 6-inch wire-wound gun is reported to have withstood the remarkable test of 1,000 rounds, 500 of which were with 44-pound charges of prismatic powder and projectiles weighing from 127 to 136 pounds; 50 of the 500 rounds gave a mean pressure of 19.7 tons.

Mr. Longridge, who furnished the original design upon which the gun was constructed, adds, in a letter to the London Standard, that at the end of this series of 1,000 rounds the gun was taken to pieces, and a new A tube put in at a cost of something like $500, since when it had fired upwards of 500 rounds, and the firing would be continued up to 1,000.

This is the same gun reported in No. VII, p. 355.

A second gun of similar construction fired about 500 rounds, when the tube failed at a point not far from the muzzle and well in front of the wire winding.

CANET 15-CM. B. L. GUN.

This gun is one of a lot destined to form the armament of the Greek armored vessels built by the Forges et Chantiers de la Méditerrannée, Graville, near Havre.

The only published details of any value are the following: The gun is of steel, 36 calibres long, and is mounted on a Canet front-pivot carriage. Four rounds were fired. The muzzle velocity of the 92.6-pound projectile was 2,263 foot-seconds. (This is equivalent to a muzzle energy of 3,288 foot-tons, and a perforation of 13.7 inches of wrought iron.)

24-CM. STEEL B. L. MORTAR.

It is reported that the French Navy has in course of preparation a design for a 24^{cm} steel breech-loading mortar, destined to form part of the upper-deck battery of armored vessels.

GUN TRIALS.

PNEUMATIC DYNAMITE GUN.

The following is taken from the report of the "Board on Trial of Dynamite Guns" upon the experiments for accuracy made with a 15-inch dynamite gun on January 19 and 26, 1889, at Fort Lafayette, N. Y.:

The intention of the company was to demonstrate the capacity of the gun to throw 200 pounds of high explosive between the limits of at least a mile and 200 yards, grouping 50 per cent. of the shots of each series in a target 150 long by 50 feet wide.

One member of the Board, furnished with a theodolite, was near the gun to measure the deviation of the projectiles. A second member, also using a theodolite, took up a known position on shore, approximately opposite the target, to measure the error in range. In this way the exact point of fall in each case was plotted on a horizontal plane. The character of the flight and of the explosion was observed by a third member of the Board from a tug anchored about 400 yards distant from and abreast or the target.

The dynamite employed throughout was that known as No. 1, containing 75 per cent. nitro-glycerine. The depth of water at each point could not be determined very closely, but it may be assumed as from 5½ to 6 fathoms.

The series of shots at the range of over a mile was set for January 19. On the first round, the projectile being a 10-inch sub-calibre loaded with 178 pounds dynamite, it was discovered that a leak of air was taking place through or near the firing-valve of the gun, which would probably prevent the completion of the experiments. For this reason further trials were abandoned pending investigation into the cause of the trouble.

In order to demonstrate the ability of the gun to project a large mass of high explosive with safety, a full-calibre projectile, loaded with 200 pounds of dynamite No. 1 and 300 pounds of explosive gelatine, was thrown about 1,200 yards, tumbling in its flight. The crater formed by the explosion of this shell was something unusually fine, even in the eyes of those accustomed to torpedo explosions. In this connection it may be well to note that no such mass of explosive has ever before been fired from a gun of any description.

The leak of air already mentioned was found to be through the metal of the valve itself, a porous and therefore defective casting. This was remedied, the metal made tight by tinning, and on January 26 the trials were resumed, as follows:

(1) Nine shots (from 3 to 10) were fired at about 2,100 yards' range.

(2) The next shot was meant to drop a short distance from the muzzle, to show the completeness of control over close ranges. It stuck at the muzzle. The cut-off acted when but 10 pounds of pressure had been lost; a favorable enough operation from the mechanical stand-point, but too quick for target practice.

(3) Three shots were fired at about 360 yards.

(4) To show that ranges within even 100 yards can be compassed by this gun, a short plug—a piece of iron pipe loaded with sand and weighing 346 pounds—was tossed about 90 yards.

(5) Three projectiles were fired at an intermediate range of about 1,700 yards.

(6) A sand-ballasted full-calibre projectile was thrown over three-quarters of a mile as an experiment towards getting a range table.

(7) To cover another intermediate range, the twenty-first projectile was thrown to a distance of 500 yards.

It will be observed that the short ranges were estimated, not measured. The observer was very close to the points of impact and to a series of buoys laid out at known intervals. It is believed that the error introduced is inconsiderable. To bring the shore observer back to the target would have involved much delay, with possibly, the day being short, the necessity of postponing this set of firings to another occasion.

The flight of the projectiles.—Four full-calibre (or 15-inch) projectiles were fired. Numbers 2 and 20 tumbled. Number 23 wobbled, and number 22 flew steadily. Numbers 2 and 23 were loaded with explosive; numbers 20 and 22 with sand. It is probable that in numbers 2, 20, and 22 one or more of the vanes were stripped from the tail by the after-blast, which occurs when the body of the shell clears the muzzle, for in the firing of January 26 the vanes were seen to fly in the air and land about 100 yards from the gun.

The Board was informed that an examination of the tail of a shell made at the same time as those fired showed that the vanes had been put on with screws of but one-half of the cross-section of metal as compared with those used on shells which had gone steadily. This is of course a mechanical defect which can be easily remedied, but it should be mentioned as doubtless accounting for the only bad flights in the series, and as a point to note in the inspection of service projectiles.

Every sub-calibre projectile was steady in flight, a fact which goes to prove that wobbling and tumbling will be entirely overcome in 15-inch shells, as it was in their predecessors of 8 inches diameter.

At short ranges, the rotation of the projectiles through the action of the resisting air on the vanes was distinctly noticeable, both from the neighborhood of the gun and from a point abreast of the target.

Action on the firing mechanism.—No hang-fires were observed, the discharge of the projectile following immediately upon pulling the firing-lever.

A defect exists in the gun at Fort Lafayette, which, it is understood, the company has remedied in those of the *Vesuvius*. The defect and the remedy are thus explained: In manipulating the gun for firing, it is brought to a "cocked" or "ready" position by moving the firing-lever to a predetermined set position. When the lever is pushed directly forward throughout the entire stroke to the firing position, passing the "cocking" point without stopping, the loss of air becomes irregular. On the other hand, when the lever is brought to the cocked position, it can be left there for any required time without ill result.

The firing-lever is interlocked with the breech mechanism, so that the gun can not be fired unless the breech is absolutely locked. At the time of firing it was found that the interlocking arrangement caused the firing-lever to move with considerable friction. In pushing the lever, it would move hard at first, and in the attempt to get it to the cocked position the friction ceased suddenly, so that the lever passed this position, and went over to the firing point without rest or pause.

This accident occurred in the fifth and ninth rounds, and vitiated the practice by introducing into the table two shots that were not thrown with the predetermined energy. Of course if this defect were inherent and irremediable, the whole system would be the less valuable, but in fact a simple detent to catch the firing-lever at the ready point is to be applied to the guns of the *Vesuvius*. The Board was of the opinion that rounds five and nine might with propriety be neglected in estimating the accuracy.

The range of the gun.—The twenty-second shot is notable as showing the range of the 15-inch projectile, carrying 500 pounds of high explosive, to be practically beyond a mile, as the loss of a few more pounds of pressure would certainly have carried it over the 16 yards by which it fell short of that distance. It is the more to be regretted that No. 23 wobbled, since, with the loss of 310 pounds of pressure, a phenomenal record might have been expected.

In the twenty-third round a shell carrying 220 pounds of sand was thrown to the distance of about a mile and three-quarters.

In the practice the Board found shots singly or in groups to fall 3,012, 2,100, 1,660, 1,490, 1,360, 1,200, 500, 360, and 90 yards from the muzzle of the gun. When a range table has been developed, there appears to be no good reason why the projectiles should not be placed near or far, at the will of the operator, with much accuracy, within the limit just quoted.

The quantity of explosive carried.—The Board was informed that the principal group would be fired at about 2,100 yards distance and that the charge would be 200 pounds or more of dynamite in a sub-calibre projectile. An inspection of the tabulation of this series will show that but one projectile of the lot contained that quantity of high explosive, No. 10, which carried 201 pounds of explosive gelatine. This error on the company's part was due to the maker of the dynamite, who gave a wrong figure as the specific gravity of his product. The capacity of the shells was calculated on that basis—the shells ordered, manufactured and delivered, the firing day set, and the Board convened to witness the experiments. On filling the shells they were found to take but about 170 pounds of the dynamite furnished, the specific gravity not corresponding with the maker's promise. An identical projectile carried 220 pounds of sand to a distance of 1.75 miles; a second carried over 200 pounds of explosive gelatine to a distance of 1.19 miles, and a full-calibre projectile took 500 pounds of sand to within 50 feet of the mile. Had more explosive gelatine been at hand, the company would have cast aside the dynamite and finished the series with gelatine; but gelatine is not an article of commerce here, being exclusively made abroad.

The company decided, therefore, to make the practice with the material at hand, submitting that shot No. 10 showed the ability of the gun to reach the desired range with ease. The Board accepted this view and decided that the result of round No. 10, so far as the explosive charge and range are concerned, should be accepted as typical of the group.

Action of the projectiles on impact.—But one projectile out of twenty-three fired broke up on striking the water. Its previous behavior had been abnormal, as will be seen by reference to the table (see No. 4). Contrasting it with round No. 6, it will be seen that both had the same weight, and practically the same time of flight and amount of energy stored up, yet they differed in range by 142 yards. It is evident that something had happened to retard its passage through the air, something which also affected its integrity as a whole, as well as the electrical circuits from battery to fuse, since it failed to explode.

With this single exception as to impact, and the three exceptions already noted as to character ot flight, the remedy for which is already provided, the projectiles behaved well in air and kept together on impact until the charge was detonated.

Character of detonation—fuses.—Eleven loaded and fused projectiles were fired. One failed to explode as just described. As ten out of the eleven were detonated fully it is fair to say that this feature was satisfactory.

The fuses were quick and satisfactory in their action on impact except in round No. 11. Here the alternate firing system came into play, detonation occurring on the bottom and giving a fine column of water with much mud.

Delayed-action fuses were employed in rounds 9 and 23. By mistake, no effort was made to measure the brief lapse of time between impact and explosion in the case of No. 9. In No. 23 this lapse was about 40 seconds. These times mark the limits of slight and great delays. But speaking generally, the delay action in these fuses is based on correct principles and is satisfactory in practice. In short, the fuses were found to be effective impact fuses with adjustable delayed action, and the immersion fuses certain in their action.

Accuracy of fire.—The projectiles fired at 2,100 yards range were nine in number. Of these nine, four fell in the same space, 150 feet long by 50 feet broad, with the trial shot. The remaining four were abnormal. No. 4 was the projectile which went to pieces on impact, and which appears to have previously suffered some mechanical injury. This shot should be counted either as against the gun or the projectile, not against both. Had the shell been normal, the gun would, in the opinion of the Board, have put it near No. 6.

Nos. 5 and 9 have been previously discussed. If they are not counted as part of the 2,100 yards series for the reasons given above, then but two bad shots were made at this range—No. 4 (defective shell) and No. 10, whose weight differed somewhat from the others as already described.

In the group Nos. 13, 14, 15, at close range (360 yards), it will be seen from the table that one fell within 30 feet of the trial shot and one 150 feet beyond.

At the intermediate range (1,700 yards) one fell within the same standard target as the trial shot, and one fell 24 feet short of the target.

A very interesting photograph of a projectile in air toward the end of its flight shows at that point that its axis was inclined about 15 degrees from the horizontal. It is believed that the estimate of 25 degrees at the finish errs, if at all, on the side of excess.

On striking the water, the projectiles do not follow the ordinary law of refraction; on the contrary, they always appear to take a direction but little inclined to the horizontal plane. This appearance has been noted by many observers on various occasions; but until January 26 it was impossible to say that the appearance was not illusory. Fortunately, the exact distance between the fall of the projectile No. 11 and the crater formed by its delayed explosion was measured with a theodolite. It showed that this projectile ranged 53 yards under water before detonation. Assuming it to have reached the bottom, it follows that its course after entering the water was inclined 11 degrees to the horizon. Of course it may be urged that the shot had buried itself deep in the mud before exploding; but, as it is equally permissible to hold that the projectile was still traveling onward when it burst, it is thought fair to use the observations as they stand for the purpose of illustration, leaving to the future the numerical evaluation of the law of this subaqueous projectile.

The method of graphic analysis employed to ascertain the effect produced by the groups of shell fired at the three principal ranges shows that a moderate-sized ship, broadside on, whose centre was anywhere between the limits of 1,988 yards and 2,218 yards, would have been struck by from one to five projectiles, either above or below the water-line.

If end on, her centre being from 1,046 yards to 2,248 yards removed from the gun, she would have received from one to seven of the nine shots fired. Again, were the ship an average ironclad, 333 feet long, with corresponding draught of water, etc., she would have received all of the nine shots either above or below the water-line when 2,097 yards distant.

There is, however, another effect which ought not to be neglected, viz, the torpedo action of a suitably-fused shell passing under the ship. As the lateral errors are insignificant throughout the various series, it is fair to assume that the chances of inflicting damage on a vessel, either way placed, are thereby materially increased. Since the *Silliman* was destroyed in this manner such a supposition is logically admissible. Granting that it adds only one more chance to each phase, and we see that of the nine shots fired at 2,100 yards eight would have been effective against a 300-foot ship end on and distant from 2,115 yards to 2,126 yards.

At the 1,700 yards range a similar ship, broadside on, would have been struck by from one to three projectiles, according as her centre passed over the space between 1,625 yards and 1,745 yards. On the other hand, if end on, she would have received an equal number when changing her distance between 1,574 and 1,786 yards; and the number of injuries received might be increased from one to two or from two to three within the same limits through torpedo action.

At 300 yards' range, a ship broadside on would have received from one to three shots between the limits of distance of 329 yards to 451 yards. End on, she would have received from one to three shots between the limits of 298 yards and 482 yards.

The angle of fall is assumed to be the same as before, 25 degrees, for the purpose of illustration. Whether this is true at such varying ranges is not known. An increase of the danger zone, by torpedo action, similar to that pointed out at the other ranges, may also be granted. The distance selected in advance for this group was 2,100 yards.

It appears finally, then, that projectiles either carrying or capable of carrying 200 pounds of high explosive were thrown to distances varying from 1¾ miles to 90 yards, and that, at the ranges selected for grouping, viz, 2,100 yards, 1,700 yards, and 360 yards, not less that one-half of the projectiles fired fell in the same standard target with the trial shot.

The Board was of the opinion that sub-calibre projectiles smoother on the exterior and of greater excellence and uniformity of manufacture would have yielded better results even than those recorded; for, excepting in the fifth and ninth rounds, the losses of air pressure and therefore the energy stored up in the moving projectile, were remarkably regular. In shells of identical make the flights would have been correspondingly uniform.

[Indorsement by the Secretary of the Navy.]

NAVY DEPARTMENT,
Washington, February 21, 1889.

The test for accuracy of the pneumatic dynamite gun, the results of which are recorded in the within report, are satisfactory to the Department, and notice may be given to the company to that effect.

The substance of the report is that, taking as a target a space upon the surface of the water 50 by 150 feet (which is considerably less than would be occupied by an ordinary vessel of war), and marking out by buoys one such target at 360 yards, another at 1,700 yards, and a third at 2,100 yards from the muzzle of the gun, the points being selected by range shots, the pneumatic power worked with such accuracy that more than one-half of the projectiles fired at the respective ranges fell within the target in each case. These results are more than satisfactory.

The effective range of the guns is also shown to be largely in excess of the requirements of the statute and contract. The law provided for dynamite guns "of a 10½-inch calibre, and guarantied to throw shells containing 200 pounds of dynamite or other high explosive at least 1 mile."

The company constructed the guns of 15-inch calibre instead of 10½ without additional expense to the Government, and this report records the fact that—

"The twenty-second shot is notable as showing the range of the 15-inch projectile carrying 500 pounds of high explosive to be practically beyond a mile, as the loss of a few more pounds of pressure would certainly have carried it over the 16 yards by which it fell short of that distance."

In another portion of the report, referring to the explosion of a projectile containing 500 pounds of dynamite, it says:

"The crater formed by the explosion of this shell was something unusually fine even in the eyes of those accustomed to torpedo explosions. In this connection it may be well to note that no such mass of explosive has ever before been fired from a gun of any description."

A 220-pound projectile was thrown a distance of about one mile and three-quarters.

Minor defects in the working of the mechanism of a new weapon, such as this is, are to be expected until by practice and experiment details shall in all respects have been perfected. The general results of these experiments must be deemed to mark a notable event in the progress of the arts with which this Department is concerned.

W. C. WHITNEY,
Secretary of the Navy.

Statistical record of firings January 19, 26, *and* 31, 1889.

EXPERIMENT OF JANUARY 19.

[S. C. sub-calibre. F. C. full-calibre. D. dynamite. G. exp. gelatine. S. sand. Q. quick. Del. delayed action. Ex. excellent; full.]

Serial number of shot.	Projectile.			Fuse.	Time of firing.	Elevation of gun.	Pressure.			Wind.		Flight of projectile.			Fall of projectile from zero point.				Explosion.		Remarks.
	Nature.	Charge.	Total weight.				Initial.	Final.	Loss.	Direction.	Force.	Time.	Character.	Range.	Over.	Short.	Right.	Left.	Beyond point of fall.	Character.	
		Lbs.	*Lbs.*		*P. M.*	*Deg.*	*Lbs.*	*Lbs.*	*Lbs.*	*Pts.*		*Secs.*		*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*		
1	S. C.	D 178	458	Q ...	2. 40	18	1, 000	865	135	14	5	......	Steady....	2, 030	......	......	......	......	Slight...	Ex..	
2	F. C.	D 200 G 300	950	Q ...	3. 22	35	900	735	165	14	5	......	Tumbled..	1, 180	......	......	......	......	..do	Ex..	A demonstration not in accuracy series.

EXPERIMENTS OF JANUARY 26.

Serial number of shot.	Nature.	Charge.	Total weight.	Fuse.	Time of firing.	Elevation of gun.	Initial.	Final.	Loss.	Direction.	Force.	Time.	Character.	Range.	Over.	Short.	Right.	Left.	Beyond point of fall.	Character.	Remarks.
3	S. C.	S 170	450	......	*A. M.* 11. 14	18	1, 000	875	125	8	2–3	......	Steady....	2, 177	......	......	......	......	....	......	Reference shot.
4	S. C.	D 172	452	Q ...	11. 31	18	1, 000	878	122	8	2–3	11¾	....do	2, 017	......	160	6	......	....	Nil..	Shot broke up on impact and pieces scattered.
5	S. C,	D 173	453	Q ...	11. 47	18	1, 000	895	105	8	2–3	12¼	....do	2, 009	......	168	10	......	Slight...	Ex..	
6	S. C.	D 172	452	Q ...	*P. M.* 12. 02	18	1, 000	877	123	8	2–3	12	....do	2, 159	......	18	6	......	..do	Ex..	
7	S. C.	D 165	445	Q ...	12. 13	18	1, 000	875	125	8	2–3	11¾	....do	2, 155	......	22	8	......	..do	Ex..	
8	S. C.	D 167	447	Q ...	12. 25	18	1, 000	877	123	8	2–3	12	....do	2, 127	......	50	......	......	..do	Ex..	
9	S. C.	D 173	453	Del .	12. 40	18	1, 000	890	110	8	2–3	11⅖	...do	2, 025	......	122	......	2	Greater..	Ex..	Explosion took place 4 yards to right of impact.
10	S. C	G 201	483	Q ...	12. 47	18	1, 000	780	220	8	2–3	13	....do	2, 091	......	86	......	4	Slight...	Ex..	Explosive gelatine with dynamite core.

Statistical record of firings January 19, 26, *and* 31, 1889—Continued.

EXPERIMENTS OF JANUARY 26—Continued.

[S. C. sub-calibre. F. C. full-calibre. D. dynamite. G. exp. gelatine. S. sand. Q. quick. Del. delayed action. Ex. excellent; full.]

Serial number of shot.	Projectile.			Fuse.	Time of firing.	Elevation of gun.	Pressure.			Wind.		Flight of projectile.			Fall of projectile from zero point.				Explosion.		Remarks.
	Nature.	Charge.	Total weight.				Initial.	Final.	Loss.	Direction.	Force.	Time.	Character.	Range.	Over.	Short.	Right.	Left.	Beyond point of fall.	Character.	
		Lbs.	*Lbs.*		*P. M.*	*Deg.*	*Lbs.*	*Lbs.*	*Lbs.*	*Pts.*		*Secs.*		*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*		
11	S. C.	D 160	440	Q ...	12.56	18	1,000	875	125	8	2–3	12⅕	....do	2,153	......	24	4	......	53.......	Ex..	Detonation on bottom; much mud thrown up.
12	S. C.	S 220	500	......	....	18	1,000	990	10	8	2–3	......	....	....	......	......	......	......	....	......	Projectile only reached the muzzle.
					P. M.																
13	S. C.	S 213	493	......	3.00	18	1,000	980	20	12	1	3½	Steady....	360*	......	......	......	......	....	......	Reference shot.
14	S. C.	S 214	494	......	3.05	18	1,000	978	22	12	1	5	....do	410*	50	......	......	½	....	......	
15	S. C.	S 215	495	......	3.08	18	1,000	980	20	12	1	5	....do	370*	10	......	......	......	....	......	
16	F. C.	S	346	......	3.14	18	1,000	988	12	12	1	......	....do	90*	......	......	......	......	....	......	An iron plug filled with sand.
17	S. C.	S 213	493	......	3.35	18	1,000	913	87	12	1	10	....do	1,704	......	......	......	......	....	......	Reference shot.
18	S. C.	S 215	495	......	3.45	18	1,000	913	87	12	1	10½	....do	1,665	39	......	......	......	....	......	
19	S. C.	S 213	493	......	4.01	18	1,000	914	86	12	1	10½	.. do	1,646	58	......	......	......	....	......	
20	F. C.	S	925	......	4.20	35	1,000	815	185	12	1	16	Tumbled..	1,490	......	......	......	......	....	......	Not in accuracy series.
21	S. C.	S	450	......	4.30	18	1,000	975	25	12	1	5⅓	Steady....	500*	......	......	......	......	....	......	Do.

EXPERIMENTS OF JANUARY 31.

Serial number of shot.	Nature.	Charge.	Total weight.	Fuse.	Time of firing.	Elevation of gun.	Initial.	Final.	Loss.	Direction.	Force.	Time.	Character.	Range.	Over.	Short.	Right.	Left.	Beyond point of fall.	Character.	Remarks.
22	F. C.	S 500	980	......	12.01	35	1,000	810	190	1	6	17	Steady....	1,744	......	......	......	......	....	......	
23	F. C.	G 500	980	Del .	12.58	35	1,000	690	310	1	6	15	Wobbled .	1,365	......	......	......	......	....	......	
24	S. C.	S 220	500	......	1.15	35	1,000	725	275	1	6	18	Steady....	3,012	......	......	......	......	....	......	Same shell as No. 12.

* Estimated.

PITTSBURG STEEL-CAST GUN.

The particulars of the terms of the contract under which the gun was made are given in No. VII, p. 342. The statutory test preliminary to acceptance took place on the Annapolis Proving Ground on December 5, 1888. The gun was mounted on a hydro-pneumatic carriage which had been previously tested by firing a standard 6-inch gun. The gun was carefully star-gauged before firing. A preliminary round with 36 pounds of brown prismatic powder and a 100-pound projectile was first fired to heat the gun and to insure the fitting of the obturator. The past record shows that this charge and projectile give 1,700 foot-seconds velocity and 10.5 tons pressure. After a delay of fifteen minutes, requested by the superintendent of the Pittsburg Steel Casting Company's Works, with the object of permitting the heat of the first discharge to penetrate through the mass of the gun, the statutory test was begun. The record of the 48.5 charge of the powder used shows that it is capable of imparting to the 100-pound projectile an initial velocity of 2,000 foot-seconds and gives rise to a chamber pressure of 15 tons.

The gun burst at the first round. The breech was torn off in almost a perfect ring, 6 inches long, and blown to the rear a distance of 130 feet; the breech plug remained locked in the piece and was unlocked and withdrawn without effort; twenty large fragments were recovered, one, weighing about 600 pounds, at a distance of 90 feet from the firing position. The three pressure gauges were unimpaired; their average record was 14.1 tons. The appearance of the fracture was in many cases peculiar; only two flaws were detected, but there was a striking lack of uniformity on the granulation at different points. No one of the firing party was injured.

THURLOW STEEL-CAST GUN.

This gun, the earlier history of which is given in No. VII, p. 342, was subjected to the statutory test at the Annapolis Proving Ground on February 7.

The mount was a wooden 100-pounder shifting-pivot carriage, which had been especially prepared. The slide was placed at an angle of 10 degrees with the horizontal to facilitate returning the gun to battery, and two extra compressors were placed in the carriage.

The gun was star-gauged just previous to the firing, and a careful examination made of both exterior and interior. The bottom of a blow-hole, about half way down, was the only defect that could be detected. It was too slight to be measured with the gauge.

The projectiles weighed 100 pounds each. The charges were such as to give a velocity of 2,000 foot-seconds and a chamber pressure of 15 tons. A preliminary round, with a charge of 36 pounds, was first fired to adjust the obturating pad. As the first one showed signs of leaking, a second round of 36 pounds was fired with a new pad ten minutes later. About three minutes afterward the test of ten rounds with full charges was begun, and was completed in nineteen minutes eight seconds. This is seven minutes twenty-five seconds longer than the time required for the test of the service 6-inch. The difference must be attributed to the necessity, with the old-fashioned carriage, of returning the gun to battery by hand after each round, and the greater time occupied in sending the larger crew to shelter.

On the morning of the following day the gun was again star-gauged and a careful examination otherwise was made. Near the seat of the projectile, 54 inches from the base of the breech, was found a score extending across the fifth band and groove (counting from bottom to right). At 58 inches from the base of the breech was a score extending across bands 3 and 4 (counting to the left) and the intervening groove; and at 57 inches from the base of the breech another was found across bands 10 and 11. These scores are all too narrow to be measured with the gauge.

The permanent enlargement in the chamber was about .004 inch; near the seat of projectile, .007 inch.

PNEUMATIC CARRIAGE FOR 8-INCH B. L.R.

Description.—In this carriage, designed and built for the Navy Department by the Pneumatic Gun Carriage and Power Company, the gun is mounted in the ordinary manner by its trunnions in bearings formed in a top carriage, A, which hooks under flanges A^1, formed on the top of the slide A^2, and moves horizontally on recoil instead of up an incline as in carriages of the ordinary hydraulic type. The reason for this is hereinafter explained. At the front the cheeks forming the slide are connected by a transom, A^3, and secured to a bed-plate, B, provided with brackets B^1, in which are pivoted three truck rollers B^2. The rollers have grooves which work over a projection of corresponding shape formed on a circular bed-plate, B^3, which supports the front of the carriage and the weight of the gun when in battery. In the centre of this circular plate (which is secured to the deck of the vessel), and also in the bed of the carriage, is formed a bearing, B^4, for a pivot around which the carriage turns. On the circular bed B^3 is a projecting flange, under which the clips B^5 hook to prevent the carriage from lifting. The rear end of the carriage is secured to a transom, C, in which are pivoted four truck rollers, two being placed under each cheek of the slide; these rollers also have grooves which fit over a projection on the circular traversing ring D, provided with a projecting flange for clipping down the rear end of the carriage. To two downward projecting arms E on the top carriage are secured piston rods and pistons E^1, which work in the pneumatic recoil cylinders E^2. Each recoil cylinder and its cheek are cast in one piece, and the tops of the cylinders are made on a line with the tops of the cheeks so as not to interfere with the sighting of the gun. These recoil cylinders are supplied with compressed air by a pipe communicating through the pivot with a reservoir and air compressor by pipe G and stationary manifold G^1. The pistons are solid, without packing, and made less in diameter than the bore of the cylinders to allow of a displacement of a portion of the air by the recoil of the gun and pistons, thus forming nearly an equilibrium of pressure on both sides of the pistons at the termination of the recoil. The excess of pressure caused by the different areas of the cylinder on each side of the piston gradually runs the gun into battery, dispensing with the necessity of inclined slides, a matter of great inconvenience in a rolling sea.

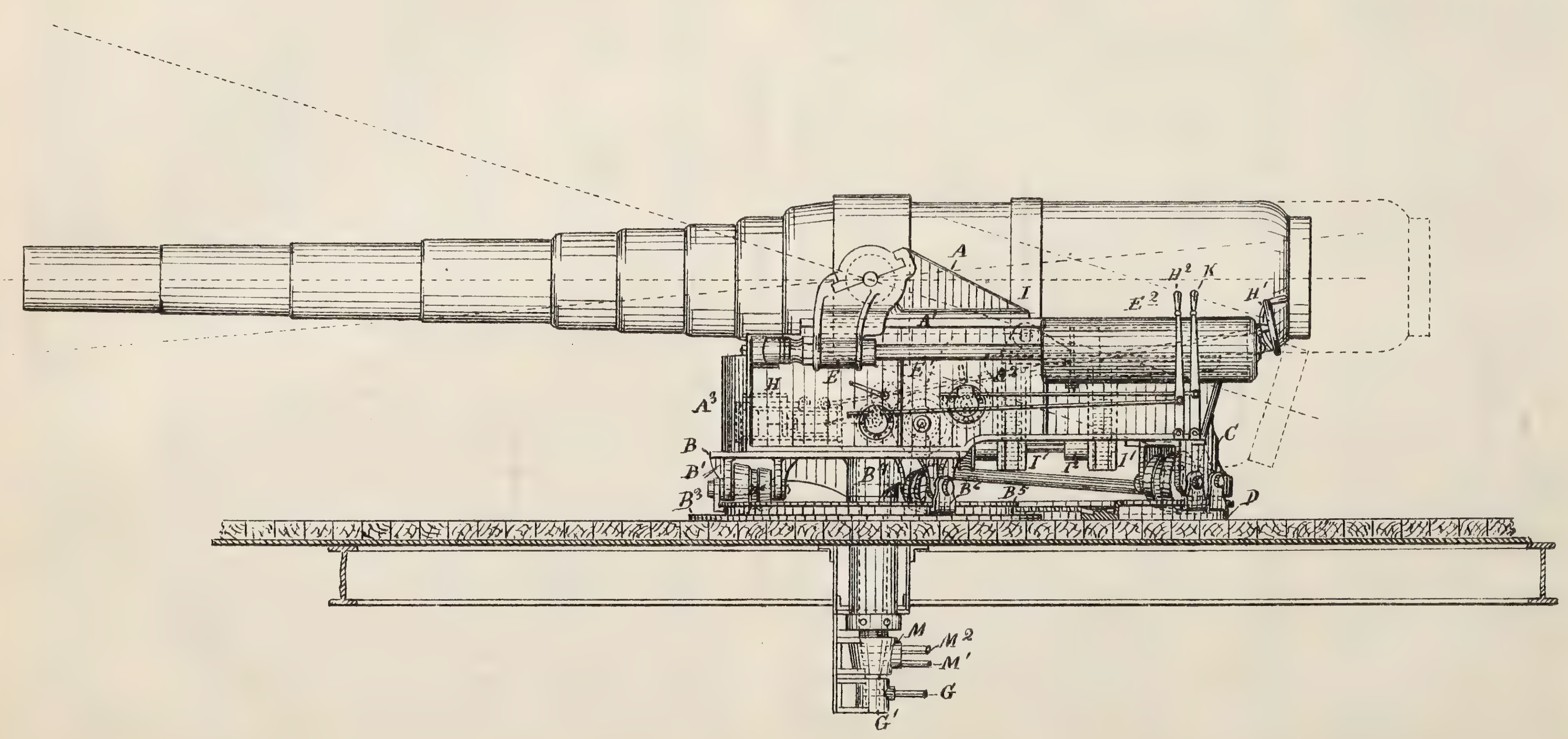
This carriage is worked mechanically by means of a small air engine, H, located in the front portion of the carriage and provided with a follow-up stop-motion valve operated by the hand wheel H^1. The traversing of the carriage is performed by the engine through the medium of reversible clutch-gears operated by the hand lever H^2, in connection with a worm gear, shaft, pinion, and rack formed on the inside of the circular traversing ring D. The traverse of the carriage ceases the moment that the turning of the hand wheel H^1, which controls the valve of the engine, is stopped.

The elevating and depressing of the gun is performed by means of two horizontal bars which are parallel with the slides of the carriage and are connected to the gun by saddles and the elevating band I. These bars are elevated by vertical racks I^1, which work in grooves in the cheeks of the carriage. Into the vertical racks engage pinions carried by horizontal shafts, which are supported by bearings I^2 formed on the cheeks of the carriage, the shafts and pinions being worked by friction worm gears and reversible clutch gears operated by the reversing lever K. This gearing is actuated by the air engine, which receives its air supply of compressed air by a communication through the pivot, the manifold M, and pipe M^1. The exhaust is through the pipe M^2. The pivot revolves with the carriage so as not to derange the pipes in the carriage, while the manifolds are stationary, so as not to derange the pipes leading to the air receivers.

The carriage can be traversed, and the gun elevated or depressed, by hand, and the operations can be performed simultaneously or singly as may be required, while the engine remains idle. The initial pressure requisite to take up the recoil of the gun varies from 250 to 400 pounds per square inch.

Pneumatic Carriage for 8 in, B. L. R.

Pneumatic G. C. & P. Co.



This carriage has been built by authority of Congress on the recommendation of the Secretary of the Navy (June, 1886). Its weight complete without the gun is about 16,000 pounds, and in future 8-inch carriages the weight is expected to be reduced to 14,000 pounds.

Trial.--The trial of this carriage took place at the naval proving ground at Annapolis. The gun mounted upon it was an 8-inch B. L., mark II; the powder charge was 126 pounds of Dupont's brown prismatic powder; the weight of projectile 250 pounds; and the powder pressure obtained on two rounds was 16.17 and 16.79 tons. The weight of the carriage as given by the contractors, including pivot sockets and tracks, is 16,400 pounds; the outside dimensions are, length, 7 feet; width, 5 feet. The gun was fired at level with the exception of one round at 14 degrees and three other rounds at 5 degrees elevation.

Two deliberate rounds were first fired, and the rapidity test of ten rounds was then begun. Three rounds were fired in less than five minutes, when the pinion on the lever of the breech-plug gave way, and the trial was adjourned until the broken part could be replaced. When continued, seven rounds were fired in 8 minutes 16 seconds.

During the trial twenty rounds were fired, and previous to this some eleven rounds had been fired with various charges. At the end of the trial the carriage showed no spread or other signs of distress.

The recoil varied between 23¼ and 24¼ inches, the air pressure in cylinders being kept at about 330 pounds by the continuous action of the air compressors. It was shown that with this carriage the pressure in the recoil cylinders fell 100 pounds in five minutes when the air compressors were shut off.

The pneumatic loading apparatus worked efficiently, and the training, elevating, and pointing of the gun were well accomplished, but could be improved by increased rapidity.

TRIAL OF PELAYO'S 28-CENTIMETRE (11-INCH) GUNS.

The two Hontoria 28-centimetre guns destined to form part of the armament of the *Pelayo* were recently subjected to a firing trial, with the following results: With a projectile weighing 838 pounds and a 353-pound charge a velocity of 2,034 foot-seconds was attained, the pressure being 16. 8 tons. The breech mechanism worked easily and regularly, and the obturation was perfect.

The powder used with these guns was made in Spain, and is of the prismatic brown variety, with one central canal. It is said that it gives results superior to those obtained with the German powders, with which a velocity of only 1,942 foot-seconds was obtained. The weight of the 28-centimetre gun is only 32. 5 tons.

While the weight of projectile above mentioned seems excessive for a gun of this calibre, the statement, originally appearing in the Revista General de Marina, bears evidence of being authoritative, and announces also that a 32-centimetre of the same type, weighing 50 tons, and intended for the *Pelayo*, will soon be tried. This gun will fire a projectile weighing 1,056 pounds, with a powder charge of 528 pounds.

TRIAL OF THE DE BANGE 32-CENTIMETRE (12.6-INCH) GUN.

This gun was built by the Cail establishment, Paris, for the exposition exhibit, and was fired at Calais in May last. The particulars of the gun and its performance, are as follows:

Length of gun	feet	41. 0
Weight of gun	tons	46. 4
Weight of projectile	pounds	880
Weight of powder charge	do	418
Muzzle velocity	foot-seconds	2, 132
Range at 10 degrees elevation	yards	10, 389
Maximum range at 30 degrees elevation	do	20, 778
Energy at muzzle	foot-tons	27, 822
Penetration in iron at muzzle	inches	35. 4

GUN-CASUALTIES.

THE BURSTING OF A 34^{cm} GUN ON BOARD THE AMIRAL DUPERRÉ.

On the 12th December, 1888, while the French squadron of evolution was engaged in target practice near Toulon, the 34^{cm} (13.4-inch) B. L. gun in the after barbette of the battle-ship *Amiral Duperré* burst, by blowing out the breech, killing an officer and five of the crew of seven men. The hood-shield covering the rear of the gun was destroyed and the neighboring boats shattered. The projectile continued its flight and fell near the target.

The gun was one of the first all-steel type introduced into the French navy, designated *modèle* 1875. At that date, when steel was adopted by the French as the material for naval guns, the art of manufacturing gun forgings was yet undeveloped and the material available was greatly inferior to that now employed. In fact, many distinguished French ordnance officers were at that time opposed to the sole use of steel, and preferred the type (*modèle* 1870), in which a cast-iron body (*corps du canon*) was strengthened by a steel tube and a series of exterior steel hoops.

Briefly, the 34^{cm} gun *modèle* 1875 consisted of a tube inserted in a *corps du canon;* the latter in two pieces, the rear part corresponding to a jacket and the forward part extending from before the trunnions to within about 3 calibres of the muzzle, and two series of hoops, extending from the rear end to a point 3 calibres in front of the trunnions. The breech-plug engaged in the jacket. The total length of the gun was about 20 calibres; its weight, 47.5 tons. For fuller description of construction, see page 140 (chapter IV).

The powder-charge originally fixed for the gun was 258 pounds of prismatic powder, Wetteren 30/38 (the figures indicate the dimensions of grains in millimetres); weight of projectile, 926 pounds. With the introduction of the slower-burning brown powder the powder-charge was changed to 304 pounds of this powder, giving the same projectile an increase in initial velocity from 1,592 feet to 1,722 feet, without increasing the pressure in bore. The gun had been fired about 80 rounds, of which 8 were with the 304-pound charges.

Immediately after the accident two causes were assigned for the failure of the gun: (1) Unsuitable material used in construction, due to the undeveloped state of the manufacture of steel gun forgings; (2) Abnormal power pressure, due to loss of moisture, change and deterioration of the powder, which, although less than two years in service, had been subjected while in the ship's magazines, situated between the boilers, to temperatures rising as high as 130° F.

An examination of the fracture showed no evidences of any fault in the metal. The jacket gave way about the second screw-thread in rear of the nose-plate, and the part blown out was broken in many pieces. None of the exterior hoops were injured, but the rear hoops were set back some 2 inches.

The Yacht, May 11, states that tests of the powder have been made at Gavre which show that the heat to which it had been subjected while on board the *Duperré* had seriously changed its character, causing loss of stability, quicker burning, and increased pressures, and remarks that it is estimated (at Gavre) that the pressure in the gun burst was more than 4,000 atmospheres (26 tons to the square inch; designed pressure about 16 to 18 tons). If the estimate is correct, it is little wonder that the gun failed.

The result of the accident has been that the *Dévastation* has recently gone to Toulon to replace her four 34^{cm}, 1875, guns with others of 32^{cm} calibre, which have cast-iron bodies, tubed and hooped with steel. The guns of the *Duperré* will be changed in the same manner.

The accident was most serious in character; but, in view of the firing conditions, the type of gun, and the changes and improvement which have been made in design and material since the date of its construction, it has led to no modification in French guns of the latest design and type. It, however, throws doubt upon the stability of new powders, whose behavior under service conditions will be closely watched.

In the course of the same target practice which caused the *Duperré* accident, it is said that the tube of a 27^{cm} gun of the 1875 model was displaced longitudinally about 12 inches, thereby disabling the gun. This also must be one of the guns in which the tube extends only as far as the obturator seat.

ACCIDENT ON BOARD THE IPHIGÉNIE.

The accident to the Iphigénie's gun in October last, it has been learned, was due to a failure to lock the breech before firing. The statement that the gun burst is incorrect; the accident is termed "déculassement," and is not an infrequent occurrence with guns not provided with a safety firing device, to which class the Iphigénie's gun belongs.

ACCIDENTS TO ENGLISH GUNS.

The blowing out of the breech of the *Caroline's* 5-inch B. L. R. is attributed by Broad Arrow to a burning residue of German powder left in the bore after the previous rounds.

On August 22d, during practice firing with a 40-pounder Armstrong gun, the breech-screw blew out, killing two men and wounding a number of others of the crew.

The gun was one of the Armstrong first type of breech-loaders, in which the breech is closed by a removable vent piece, locked in place by a screw-plug with continuous threads. The fatal round was made with a 40-pound lead-coated projectile and a 5-pound charge of powder. The accident was said to be due to the plug not being properly screwed in.

Engineering, of July 13, 1888, says: It is reported that two of the Rodney's 67-ton guns have split their liners. A section of these guns is shown on Plate I, Chapter IV. The liner, it will be seen, extends from the screw-box forward about two-thirds the length of the gun, at which point it makes a joint with another tube, known as the *a* tube. The liner is inserted with a close mechanical fit, and is a part that can readily be replaced.

Captain May, in command of the *Impérieuse*, on the China station, is said to have reported to the Admiralty the substantial disablement of her auxiliary armament of 6-inch breech-loaders. During prize-firing at Fort Hamilton it was discovered that the locks in the breech-blocks fitted so badly that they were constantly being blown out. None of the crew was seriously hurt, but there were several narrow escapes. The defects eventually became so alarming that the captain suspended the prize-firing, and continued to fire by means of the electric circuit, the gun crews lying down in the mean time. Several rounds were fired with crusher-gauges attached to the blocks, when it was found that the pressures developed by the explosion of the charges were greatly in excess of what ought to be the case with slow-burning powder.

RAPID-FIRE AND MACHINE GUNS.

The employment of rapid-fire guns is becoming much more general than heretofore, and the heavier guns of this class, varying in size from the 30-pounder, or 4-inch, to the 6-inch, now form the principal portion of the primary battery of several cruisers. The great accuracy of these guns, combined with rapidity of fire, has been also recently illustrated in trials of the 4.72-inch gun at Shoeburyness. A target six feet square, at a distance of 1,300 yards, was hit five times in thirty-one seconds. The projectile of the 4.72-inch R. F. gun weighs 45 pounds, and when fired with 12 pounds of Chilworth smokeless powder a muzzle velocity of 2,350 foot-seconds is obtained. The gun weighs a little over two tons, and is said to be capable of piercing 10.5 inches of wrought-iron. It is probable that guns of this general type will almost entirely replace the present types of guns of 6-inch and smaller calibres.

The 70-pounder R. F. G., described in No. VII, p. 360, is said to have been definitely abandoned. The cartridge, projectile included, weighed about 120 pounds, and this was found to be too heavy for rapid loading.

HOTCHKISS R. F. GUNS.

The following items regarding the Hotchkiss R. F. guns are noteworthy:

Chili has ordered six 14-pounders. France has adopted the 9-pounder and 33-pounder. Japan has ordered a 55-pounder and requires it to fire 10 aimed shots per minute with a crew of ten men. Portugal has adopted the 9-pounder.

The power of the Hotchkiss gun has been considerably increased by the employment of powders recently introduced. With the French S. P_1 powder, for which the 33-pounder was designed, an initial velocity of 2,000 foot-seconds was obtained; but by using the French smokeless powder, recently manufactured, 2,600 foot-seconds have been obtained, and in the case of the 3-pounder, in which the French C_2 powder gave an initial velocity of 2,000 foot-seconds, 2,300 foot-seconds have now been obtained by using the new smokeless powder.

DRIGGS-SCHROEDER R. F. GUNS.

The following are some particulars of the 1, 3, and 6-pounder Driggs-Schroeder R. F. guns:

	1-pounder.	3-pounder.	6-pounder.
Calibre .... inches..	1.457	1.85	2.244
Length of bore .... do....	35	81.45	100.98
Length of bore .... calibres..	24	44	45
Length of rifling .... inches..	30.768	65.75	98.3
Length of gun .... do....	38	87.26	107.98
Length of gun with shoulder-piece .... do....	52	105.75	128.9
Number of grooves	12	20	24
Depth of grooves .... inches..	0.015	0.0158	0.015
Width of lands .... do....	0.0594	0.0787	0.0737
Twist of rifling	1 turn in 30 calibres.	1 turn in 100 to 1 in 25 calibres.	1 turn in 150 to 1 in 27 calibres.
Weight of gun complete .... pounds..	73	497	800
Weight of breech-block .... do....	6	16	26
Weight of shoulder-piece .... do....	6	12	25
Weight of powder .... ounces..	2.82	27.53	31.5
Weight of projectile .... pounds..	1.1	3.3	6
Muzzle velocity of projectile .... foot-seconds..	1,375	2,050	1,880
Number of fires per minute	....	30	....

The Navy Department has purchased the right to apply the breech mechanism of this system to guns of 4-inch calibre and above, and a design for a 4-inch R. F. gun to be so fitted has been completed.

The Driggs-Schroeder 6-pounder rapid-fire gun was tried at the Naval Proving Ground May 11.

A trial was first made to see how far it was necessary to shove the cartridge home before the breech-block could be closed. It was found that the breech could not be closed with the rim of the cartridge more than three-fourths of an inch from the extractors.

The possibility of firing before the breech is closed and securely locked was next tested and it was found impossible to fire before the breech was properly closed and locked.

A number of rounds were fired to test the general working of the breech mechanism, and afterwards trial was made to ascertain the greatest number of rounds that could be fired in one minute, the crew consisting of three men, one to point and fire, one to load and work the breech mechanism, and one to pass ammunition. Eighteen rounds were actually fired, and one miss-fire occurred; making allowance for the time required to withdraw the loaded cartridge in excess of that required for an empty case, this would place the number of rounds per minute, with an unpracticed crew, at 20. The shortest time between fires was 2 seconds, and the longest 7 seconds, when the miss-fire took place.

After a number of rounds to test the facility for loading at different elevations the continuous fire test was made, during which 63 rounds were fired in 4 minutes and 23 seconds.

The platform upon which the mount was secured became loose during the trial, and the gun, not being rigidly fixed, required frequent changes of elevation.

The total number of rounds fired during the trial was 101, and the duration of trial about one hour. The breech mechanism remained cool and no injury was detected either in the breech-block or grooves. The locking device for holding up the breech-block when closed appeared satisfactory, and the strength and endurance of the breech mechanism were found to be ample.

GRUSON RAPID-FIRE GUNS.

The particulars of the Gruson R. F. guns are tabulated below:

	3.7^{cm}.	5.3^{cm}, 24 calibres long.	5.3^{cm}, 30 calibres long.	5.3^{cm}, 39 calibres long.	5.7^{cm}.
Calibre..........inches..	1.457	2.087	2.087	2.087	2.244
Length of gun..........do....	34.25	51.32	63.58	81.69	57.48
Length of bore..........calibres..	20.0	21.1	27.0	35.0	22.3
Length of rifling..........inches..	24.69	35.58	46.97	59.63	38.81
Weight of gun..........pounds..	72.75	283.3	345.0	595.2	363.3
Weight with breech-block..........do....	81.57	313.0	374.7	639.3	396.8
Weight of charge..........ounces..	2.82	12.87	12.87	19.2	22.05
Weight of shell..........pounds..	1.0	3.59	3.59	4.01	6.0
Muzzle velocity..........foot-seconds..	1,332	1,467	1,493	1,969	1,476
Maximum pressure..........tons..	9.52	11.43	11.43	12.7	11.43
Number of fires per minute..........	35 to 40	35 to 40	35 to 40	26	35 to 40

These guns are made of forged crucible steel, which on test must bear a minimum strain of 35.5 tons per square inch, with an extension of at least 15 per cent. and a minimum elastic limit of 16.5 tons per square inch. The firing test has in some cases been carried to 2,000 rounds, at the conclusion of which, it is stated, the guns "showed a complete absence of any trace of erosion, remaining, in fact, internally without alteration."

The principle of the breech action is that the cocking of the striker is effected by the downward movement of the breech-block.

The block B is cut through at the upper part to facilitate placing the charge in the chamber, and is moved up and down in a vertical slot by means of a hand-lever, A, to close and open the breech. The hand-lever A actuates a shaft, *a*, to which a crank-lever is fixed, whose pin, a^1, slides in a groove, *x*, in the block and thus moves it. To limit the downward movement there is a screw, C, which works in the vertical groove *y* of the block by means of a shoulder.

The firing mechanism consists of a striker, *b*, actuated by a spiral spring, *c*, and controlled by the thumb-lever d^1, fixed to the shaft *d*. The requisite motion is given to the shaft *d* by a second lever, d^2, which moves in a groove, *z*, formed in the side of the breech, by means of the pin d^3. This groove has an inclined direction, so that the shaft *d* has a turning motion given to it as the block descends. As soon as this has reached the limit of its movement the trigger-pin *e*, which is acted on by the flat spring f^1, engages in front of a projection on the striker and keeps the latter back during the subsequent upward movement of the block. The flat spring f^1, which is rigidly connected to the trigger-lever *f*, engages in an opening in the trigger-pin *e* and at the same time works over a cam formed on the thumb-lever d^1, by which any independent movement is avoided.

The discharge takes place in two ways, according to the purpose for which the gun is employed.

When mounted on a field carriage a lanyard is attached to the trigger f, on drawing which back the trigger-pin e is pulled downwards and the striker released. When the gun is mounted on a shielded carriage a special trigger, g, is used, with a spindle, g^1, passing through the side of the breech, provided with a thumb-lever, g^2, which presses on the lever f^2 when the trigger g is pulled. The lever sf^2 and f, together with the spring f^1, are made out of one piece and are fixed on the trigger-spindle h.

A third mode of discharge is also available, specially intended for very rapid firing. To the pin a of the hand-lever A is attached a pressure-plate, i, whose other end is fixed to the hand-lever by the thumb-screw k. This plate is provided with a nose-piece, i^1, which, as the hand-lever is drawn down, presses against a projection on the collar of the trigger g, so that shortly after the hand-lever has completed its movement of closing the breech the gun is fired. This arrangement is thrown out of gear by turning the thumb-screw k, which by means of a cam working in a cavity in the plate, withdraws the latter so that the nose-piece i^1 does not act on the trigger g during the upward movement of the block.

As the striker presses in on the base of the primer when the gun is fired it must be withdrawn before the falling movement of the block commences. To effect this a third lever, d^4, is fixed to the shaft d the arm of which has a projection lying in an indentation formed in the end of the shaft a. The turning of the shaft a by the hand lever does A not at first effect any movement in the block owing to the shape of the groove X at the back part. On the other hand motion is at once imparted by the lever d^4 to the shaft d, and the striker consequently is withdrawn.

Two levers, m^1 and m^2, fixed on the same hollow spindle m, serve to extract the discharged cartridge-case. Both levers lie in cavities made in the face of the breech, and have projections on the upper extremities which take in front of the base of the cartridge-case. There is a toe, m^3, to the lever m^2 which works on an inclined surface formed on the block, so that the downward movement of the block turns the lever. The empty case is thrown out by means of a toe on the lever m^1, which, as the block descends, is thrown downwards through the action of the projection n^1 with its nut n. Both these levers effect a quick turning movement on their axis, and the case is ejected from the chamber of the gun to the rear. In order that the toe n may pass the projection on the lever m^1 as the block rises, it is allowed a free movement on its axis. Having passed the projection it falls again by its own weight into its first position. The shoulder on the stop-screw C is arranged so as to prevent any accidental backward movement of this lever through shock or jar, as on the conclusion of the upward movement of the block it presses against the upper part of the nut and gives it the necessary turning movement. As an additional security the nut n is furnished with a small flat spring which in its initial position presses backwards, but this spring can be dispensed with.

In addition to the guns enumerated in the foregoing table the Gruson works have lately produced a 12^{cm} R. F. howitzer, which is described as mounted in a small armored turret on the Schumann-Gruson system. The piece is made of a single piece of hammered crucible steel, is 15 calibres long, and rifled with 24 parallel grooves, having an increasing twist of 1 turn in 150 to 1 turn in 25 calibres. The weight, including breech mechanism, is about 10 hundredweight.

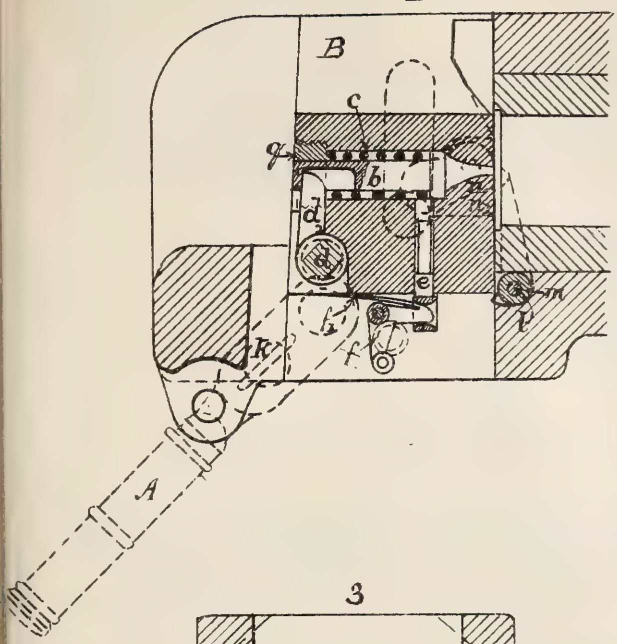
The armored carriage is fitted for the reception of six hundred rounds of fixed ammunition. Both common and shrapnel shell are used, the latter containing 450 15-gramme (about ½ ounce) balls. The powder is of a 4 to 9^{mm} (.15 to .35-inch) grain. The heaviest charge thus far employed is 2 pounds.

Two men are required to serve the gun, one to open and close the breech and fire, the other to supply ammunition and to point. The rapidity of fire is from 12 to 15 shots per minute.

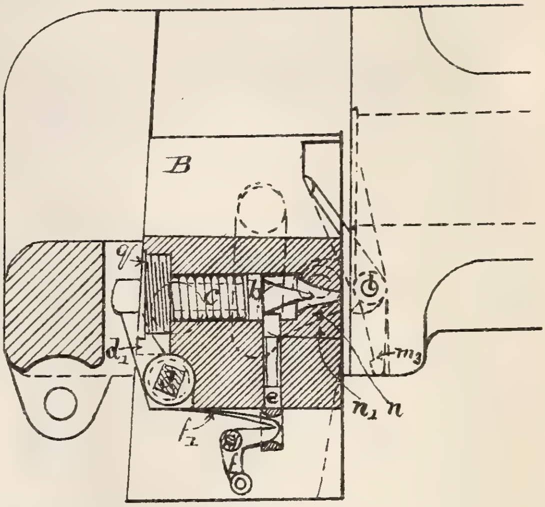
The firing trials consisted of (1) tests of the durability of the gun and carriage and the working of their movable parts; (2) determination of range tables. In all, there were fired experimentally two hundred and five rounds; both gun and carriage were pronounced faultless, and all movable parts are stated to have worked freely. In

Gruson R. F. Gun.

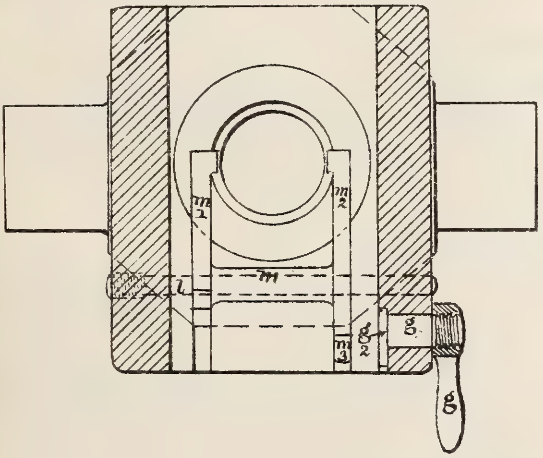
1



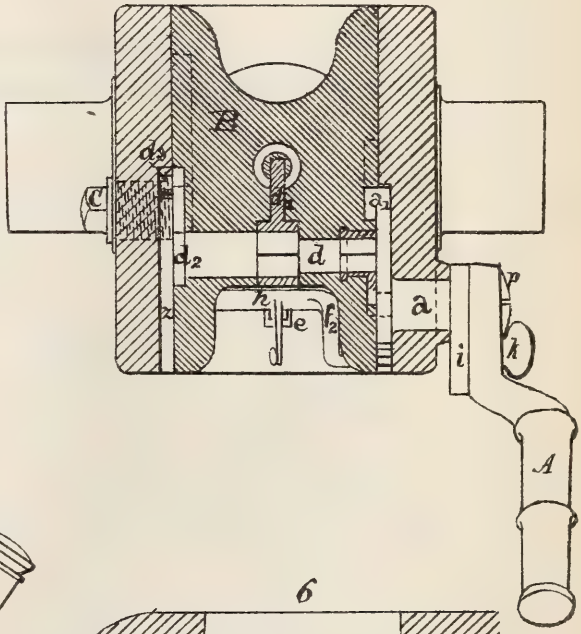
2



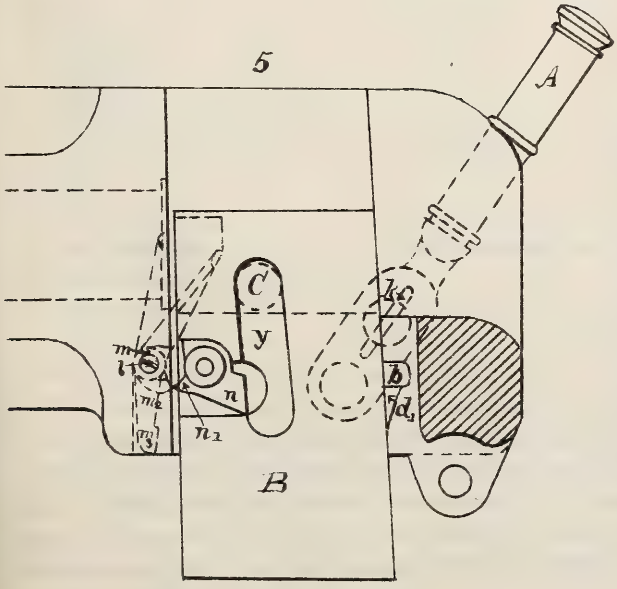
3



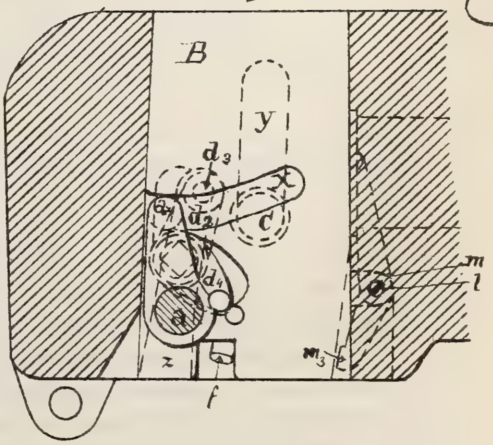
4



5



6



firing at high angles the elevation was found to change somewhat, owing to the close correspondence in weight of gun and counterpoise; this defect was obviated by diminishing the weight of the counterpoise, when the ranges became more satisfactory.

The firing was at different elevations between 5° and 35°, and the corresponding ranges were noted to 2,484 yards; the range at Tangerhutte, where the fire for range was conducted, being serviceable to only 2,515 yards.

The initial velocities recorded are as follows:

Charge.	Initial velocities.
Pounds.	*Foot-seconds.*
.66	390
1.0	525
1.3	630
1.65	725
2.0	797

Experiments with charges greater than 2 pounds will be made later.

In one series, 6 rounds were fired in 24 seconds; with shrapnel this would mean a total discharge of 2,700 balls, or 112 balls per second.

NORDENFELT AND MAXIM-NORDENFELT MACHINE AND R. F. GUNS.

The details of the Nordenfelt and Maxim-Nordenfelt guns given below are gathered from hand-books published in April, 1889:

	Maxim-Nordenfelt.		Nordenfelt.
	1½-inch machine gun.	6-pdr. R. F. gun.	14-pdr. R. F. gun.
Calibre	1.46 inches	2.24 inches	3.0 inches.
Weight	365 pounds	810 pounds	2,016 pounds.
Length of gun over all	53 inches	103.25 inches	138 inches.
Length of travel of projectile	34 inches	84 inches	106.5 inches.
Number of grooves	12	24	30.
Twist of rifling	1 turn in 30 cals.	1 turn in 180 to 1 in 30 cals.	1 turn in 360 to 1 in 30 cals.
Charge	2.82 oz. R. L. G.^{2}	1 lb. 15 oz. hexagon.	6 lb. 8 oz. hexagon.
Projectile:			
Common and steel shell	1 pound	6 pounds	14 pounds.
Shrapnel			14 pounds.
Case shot		7.9 pounds	18 pounds.
Weight of cartridge-case	4.6 ounces	2.25 pounds	7.5 pounds.
Velocity:			
At muzzle	1,319 foot-seconds	1,870 foot-seconds	2,200 foot-seconds.
At 1,000 yards	782 foot-seconds	1,296 foot-seconds	1,690 foot-seconds.
Penetration in wrought iron:			
At muzzle		4.75	7.4.
At 1,000 yards		3.26	5.6.

The mount of the 1½-inch gun is on the non-recoil system, and the breech mechanism is practically the same as that of the rifle-calibre gun described in No. VII.

The 6-pounder differs from the smaller gun in both particulars. The mount is on the rocking-slide principle; the recoil is controlled by a hydraulic buffer, and the gun is returned to battery by the energy stored up in a stout spiral spring. The breech mechanism provides for a pause in the automatic closure of the breech, during which the gun is loaded by hand. To load the gun for the first round the breech is opened by a movement of the hand-lever, which is then detached altogether, or placed in a crutch prepared for its reception. The movement of the lever has turned a crank, the action of which has brought down the breech-block, and, by means of a cam on the crank-shaft, compressed a powerful spring in a box on the side of the rocking slide. The breech-block, in moving down, strikes the lower extension of the extractor, which causes the upper portion to move out from the face of the end of the barrel and brings two small projections over the upper edge of the breech-block, thus preventing the latter from rising by the re-action of the spring. The cartridge is pushed squarely into the bore, and as it moves forward, its rim strikes against the extractor and forces back the small projections just mentioned; the spring in the side box now acts on the cam by which it was compressed, thus rotating the crank and raising the breech-block, the last upward movement of which disengages the safety-seat. After the first round the breech-block is lowered and the side spring compressed by means of a pawl engaging in a recess of the crank-cam as the gun returns to battery. The hand loading and the automatic closing of the breech take place as before.

The gun may be fired at will by pulling the trigger when required, or, if the requisite pressure be kept on the trigger, the gun will fire automatically as fast as it can be loaded.

The advantages claimed for this over all other R. F. guns are—

1. The operations of opening and closing the breech being performed by the action of the gun during its return after recoil, they can not be effected prematurely, each successive movement of the mechanism depending upon that immediately preceding it; all risk from hang-fires is thus entirely obviated.

2. The usual hand-lever not being used for working the breech mechanism the man laying the gun can devote himself entirely to that duty.

3. One man less is required for the efficient working of this gun than for any other R. F. gun of the same power.

There are two mounts for the 14-pounder, known as mark A and mark B, respectively. In the mark A the gun-trunnions are supported in a fork-shaped lever, which is centrally pivoted on a bolt passing through the brackets of the carriage, the lower end of the lever connecting to the cylinder of a combined hydraulic and spring buffer. The weight of the carriage complete, with racer, is 10 hundred-weight.

The mark B is on the rocking-slide principle. The slide pivots by its trunnions in a cross-head made in one, with the vertical pivot, which slips on an elastic cone. There are two recoil cylinders and two spiral springs, all located under the gun and well protected from the enemy's fire. The weight of the carriage is 12.6 hundred-weight; weight of cone, 7 hundred-weight.

The breech mechanism is on the well-known Nordenfelt system, viz, a breech-block (carrying the firing-pin, main-spring, and trigger) having a rotary motion imparted to it by the movement of the action-lever, and a wedge having a vertical motion on the breech-block.

There are four descriptions of projectiles supplied to the gun, viz, steel, common and shrapnel shell, and case shot. The case shot contains 364 hardened-lead balls, weighing 18 to the pound. The body is of drawn brass and is lined inside with steel segments; the base is of brass, firmly secured to the body. The shrapnel shell contains 226 balls, weighing 35 to the pound.

SMALL-ARMS.*

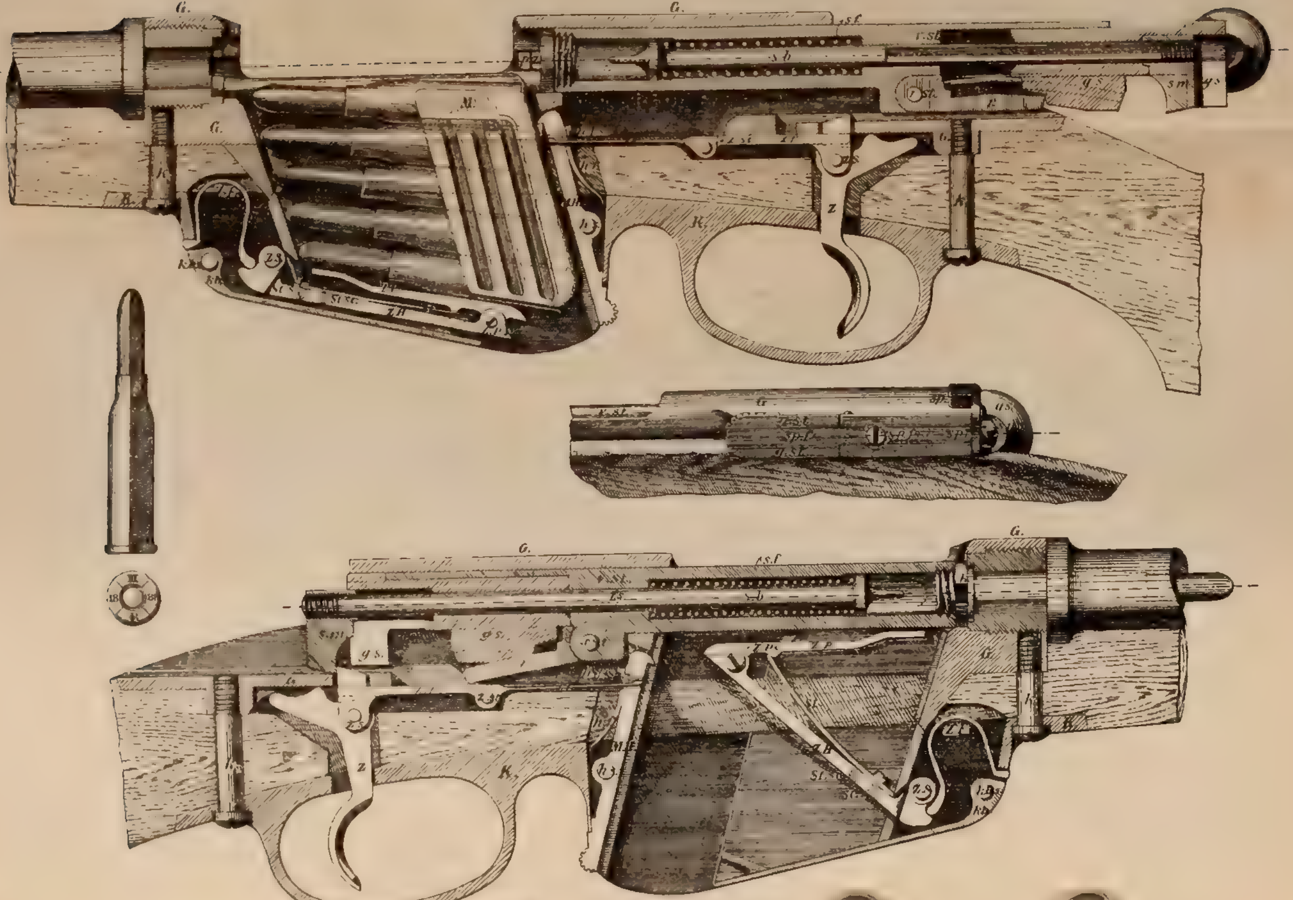
The table following represents the stage of development reached by the most advanced European countries as regards some of the characteristic features of small-arm equipment.

---

* In the temporary absence of Lieutenant Vreeland, the notes on small-arms have been prepared by Lieut. J. T. Newton, U. S. Navy.—Ed.

AUSTRIAN MAGAZINE RIFLE – M. 1888.

(Mannlicher.)



Nation.	Name.	Calibre.	Weight of rifle.	Length of rifle.	Length of bayonet blade.	Weight of bayonet.	Weight of ammunition.			Muzzle velocity.
							Powder.	Bullet.	Cartridge complete.	
		Inch.	*Pounds.*	*Inch.*	*Inch.*	*Pounds.*	*Grains.*	*Grains.*	*Grains.*	*Ft. secs.*
Austria..	Mannlicher, 88 M	.315	9.68	50.4	9.6	....	61.7	243	458	....
England .	New Army	.303	9.13	49.5	11.8	....	65.	215	430	1,800
France...	Lebel, 86 M.......	.315	9.19	51.4	20	.88	....	231	453	2,194
Germany.	88 M..............	.2953	....	....	19.7	....	....	....	....	1,950

It is noteworthy from the following account of progress that the magazine under the breech is coming into more general favor, as shown by its recent adoption in England, Germany, and, perhaps, Denmark.

Also, that the nickel or copper envelope for the bullet is displacing the steel envelope, owing to the wear which steel causes the rifling, and the liability of that metal to corrosion.

The merits of the small-calibre rifles have already been extensively dwelt on in No. VI, p.137, and No. VII, p. 366.

AUSTRIA.

The Mannlicher magazine rifle is the arm adopted by the Austro-Hungarian Government. It is manufactured at Steyr, Austria, and up to May 1, 1889, 340,000 of the 88 M. had been supplied to the Austrian army. The weekly product is said to be 8,000 rifles. The following is a description of the 88 M. (see plate):

Breech-closing mechanism.

G.	Receiver.
g. st.	Stop.
k_1	Front casing-screws.
k_{11}	Rear casing-screws.
v. st.	Bolt.
v. k.	Bolt-head.
r.	Brace.
r. st.	Brace-pin.
g. s.	Brace-quoin.
p. z.	Cartridge-extractor.
s. f.	Firing-spring.
s. b.	Firing-pin.
s. m.	Cock-notch.
Z.	Trigger.
Z. s.	Trigger-pin.
Z. f.	Trigger-spring.
Z. st.	Trigger-spring pin.
s. p.	Locking-sector.
sp. s.	Locking-sector screw.
sp. f.	Locking-spring.
sp. fs.	Locking-spring screw.

Frame with feed mechanism.

K.	Frame.
kb.	Bottom frame.
kb. s.	Bottom-frame screw.
Z. H.	Carrier-lever.
St.	Feed-spring.
St. s.	Feed-spring screw.
St. St.	Feed-spring pin.
Z. S.	Carrier-screw.
Z. P.	Carrier-plate.
Z.P.s.	Carrier-plate screw.
Z. F.	Carrier-spring.
M. H.	Packet-catch.
h. s.	Catch-screw.
h. f.	Catch-spring.
h. f. s.	Catch-spring screw.
M.	Magazine-packet.

Operation of mechanism.—The bolt-handle is drawn to the rear until the cock-notch *s. m.* passes the trigger-catch. This movement withdraws the firing-pin *s. b.*, compresses the firing-spring *s. f.*, and carries to the rear the brace-quoin *g. s.* A projection on the brace *r.* at the same time slides up the incline (shown by the dotted lines) in the brace-quoin *g. s.*, thereby raising the brace *r.* until it is clear of the recoil-shoulder, and freeing the bolt *v. st.* for withdrawal as far as the stop will permit.

The stop which limits the withdrawal of the bolt is located on the left of the casing, and retains the bolt by the pressure of the locking-spring. A projection on the stop projects through the receiver and engages in the bolt.

The extractor is pivoted near the middle of the bolt. The fore end is shaped like a claw, which takes over the cartridge-rim; the rear end carries a projection which fits into a recess in the brace-quoin *g. s.* As the brace-quoin *g. s.* is drawn to the rear this projection passes out of its recess, and thereby forces the claw at the fore end to grip the cartridge-rim.

On shoving the bolt to the front the cock-notch *s. m.* remains in rear of the trigger-catch, while the brace-quoin *g. s.* continuing its movement forces the brace *r.* down into place against the recoil-shoulder, and the projection at the rear end of the extractor, resuming its socket in the brace-quoin, locks this latter against accidental dislocation.

The piece being cocked and ready for discharge may be locked by means of a locking-bolt, which is operated by means of a locking-sector, *s. p.*, on the left of the breech. In the locking position the locking-bolt projects in front of the cock-notch *s. m.*, which would be prevented from moving to the front if accidentally released by the trigger Z.

The magazine-packet is a light steel frame, containing five rounds, arranged horizontally, with their base-rims lying in the vertical groove at the rear end of the packet. The packet is dropped from above into the magazine, where it is held between the packet-catch *M. H.* and the carrier-plate *Z. P.* which bears only against the bottom round. The carrier-plate *Z. P.* moves up between the sides of the packet as the rounds are expended, and when the last has been fed its upward pressure on the packet will cease, and the packet will be ejected downward by the action of the packet-catch *M. H.*

Dimensions and weights of the 88 *M.*

Weight without bayonet	pounds	9.68
Total length with bayonet	inches	59.8
Total length without bayonet	do	50.4
Calibre	inch	.315
Length of barrel	inches	30.12
Length of same rifled	do	27.3
Number of grooves (trough-shaped)		4
Depth of grooves	inch	.0078
Breadth of grooves	do	.138
Length of bayonet with grip	inches	15.28
Length of blade	do	9.65
Sight graduation	yards	2,700

The barrel is of Bessemer steel, bronzed exteriorly.

Ammunition of the 88 *M.*

Weight of round	grains	458
Length of same	inches	2.99
Weight of brass case	grains	151
Length of same	inches	1.97
Charge	grains	61.7
Bullet	grains	243
Diameter of bullet	inch	.322
Length of same	do	1.25
Weight of magazine-packet	grains	385

The core of the bullet is lead, hardened with 5 per cent. of antimony and pressed into a steel envelope .131 inch thick.

It is reported on good authority that the Government Technical Committee is experimenting with a material for envelopes composed of 80 parts of copper and 20 parts of nickel. This will cost much more than the steel envelope, but will not corrode and will not strip the rifling, which is probably the reason for the projected change.

The powder used is a mixture of saltpetre, charcoal, and sulphur.

Each magazine-packet contains five rounds, and twenty packets are supplied each man, making the weight of ammunition carried per man 7.08 pounds.

BELGIUM.

The Revue du Cercle Militaire of January 15, 1889, is the authority for the statement that competitive trials were made with the Mannlicher, Nagant, Peiper, and Schulof repeating rifles at the Beverloo camp, which resulted in their arrangement in the above order of merit. The Mannlicher rifle proved itself an excellent weapon. It is durable and simple. It was found that twenty shots per minute could easily be fired, while the others could reach a rate of discharge of only ten shots per minute, and that the magazine packet containing five rounds required hardly any more time for adjustment than is required for the insertion of a round in the bore of a single-fire rifle.

The United Services Gazette of March 26, 1889, states that the Mannlicher magazine rifle is about to be adopted.

DENMARK.

The Revista di Artiglieria e Genio of November, 1888, quotes from the Kolnische Zeitung the statement that the Danish Minister of War proposes to adopt for the Infantry a repeating arm of 8^{mm} calibre (.315 inch).

ENGLAND.

The new English army rifle, .303 calibre, is a combination of the improved Lee and Mannlicher.

Dimensions and weights of rifle.

Length of piece	inches	49.5
Length of barrel	do	30.5
Number of grooves (Metford system)		7.
Pitch of same	inches	10
Magazine of the Lee pattern, containing	cartridges	8
Weight of rifle complete	pounds	9.13
Length of bayonet	inches	11.8
Sight graduation	yards	2,800

*Ammunition.**

Length of round	inches	3.06
Weight of same	grains	430
Length of bullet	inches	1.2
Weight of same	grains	215
Diameter of same	inch	.303
Charge of powder	grains	65
Weight of case, wads, cap	do	150
Length of case	inches	2.1
Diameter of case-rim	inch	.52
Diameter of case	do	.45

The bullet is of lead, encased in a nickel or steel envelope. The steel gives the better results as regards accuracy of fire and penetration, and the copper contained in the nickel envelope might exclude the latter from use as being at variance with the decree of the International Conference; but, on the other hand, steel is liable to corrosion during storage and in damp climates. The trials at Enfield gave favorable results with the ammunition manufactured by the Lorenz Company. The description of the bullet and charge of this ammunition is given in No. VII, pp. 366, 367.

---

* The weight of round of the present .45-bore Martini is 960 grains.

The muzzle velocity required is 1,800 foot-seconds, and this has nearly been made, but with a bullet .3 inch at its base and a barrel too short for the complete utilization of the powder charge, high pressure is necessitated, and of late doubts have arisen as to whether this small-calibre bullet, with its very high velocity, would be as effective as a larger calibre bullet in stopping a rush when a charge is being made. On the other hand, however, it is stated in the London Times of September 22, 1888, that experiments made on the body of a horse to determine the wounding effect of this bullet, showed that had the animal been alive, it would have dropped at the first fire. The size of the wound may be due to the mushrooming of the bullet or to the breaking up of the envelope.

The Daily News of August, 1888, quotes in substance as follows from the report issued at Aldershot upon the experiments with the Maxim machine gun, proposed for adoption in the army, the new army rifle being tested at the same time in comparison. The ground from which the men fired had not been prepared in any way. The range had been predetermined, and the men were allowed a few trial shots. The table following gives the results:

Range.	New army rifle.				Maxim machine gun.			
	Marksmen.	Shots.	Hits.	Per cent.	Marksman.	Shots.	Hits.	Per cent.
Yards.								
1,070	32	219	160	73.05	1	305	52	17.04
1,120	32	216	159	73.61	1	328	274	83.53
1,400	32	216	175	81.01	1	300	231	77
1,900	32	335	147	43.88	1	250	159	63.6

There were nine misfires from the rifles, all of which were attributed to the ammunition. The bolt action of three rifles worked stiffly, causing slight delay. At the last distance the light failed, preventing observation of result and correction of fire. The absence of recoil permitted the men to fire about thirty times without discomfort. The rifle and its magazine may be said to have given great satisfaction.

The following account of the trials at Aldershot to test this rifle at long ranges has been summarized from the London Times of September 22, 1888. Thirty-seven men were armed with it; none of them had used it at ranges above 800 yards, but all were probably good shots. The weather was unfavorable, there was a haze, and a fairly strong wind blowing from the left rear of the firing point. Owing to the condition of the weather the men were allowed to fire at intermediate ranges of 500 and 1,000 yards before undertaking the 2,000-yard and longer ranges. The target for these ranges consisted of dummies arranged as a battalion of eight companies, each standing in quarter column. The target could not be seen by the men firing, but communication was maintained with the markers by means of telephone, and direction and elevation were corrected accordingly. The following is a tabular showing of the results:

Range.	Shots.	Hits.	Per cent.
Yards.			
2,000	370	181	48
2,400	367	96	29
2,800	629	104	16

FRANCE.

The Lebel rifle, 86 M., is the arm adopted by the French army. The daily product of this rifle is said to be 1,600. There are 5,000 machines employed in its manufacture at St. Etienne, 2,000 at Chatelherault, 1,200 at Toul. Up to September, 1888, 580,000 had been delivered. No rifle is accepted until 5,000 cartridges are ready for it. The following is a description of this arm:

It is composed of six principal parts, namely: (1) The barrel; (2) the bolt; (3) the repeating mechanism; (4) the stock in two pieces; (5) the fittings; (6) the sword bayonet.

(1) The barrel consists of two parts, the barrel proper and the receiver. The barrel of tempered steel is bronzed exteriorly. There are four grooves, turning from right to left. Each land is half the groove-width.

The receiver, which screws on the rear end of the barrel, contains in its upper part the lodgment for the bolt, and in its lower part, the lodgment for the repeating mechanism.

(2) The bolt consists of eight pieces.

(3) The repeating mechanism consists of six pieces.

(4) The stock is in two pieces, the fore arm and the butt. The fore arm contains the magazine with a capacity for eight cartridges arranged longitudinally.

(5) The fittings, of which the principal are the upper and lower bands, the trigger guard, breech screw, breech plate.

(6) The sword bayonet. The blade is quadrangular in section.

Dimensions and weights.

Length	Of the rifle with bayonent	inches	71.8
	Of the rifle without bayonet	do	51.4
	Of the barrel	do	31.5
	Of the rifling	do	28.6
Calibre limits for acceptance	Minimum	do	.3142
	Maximum	do	.3228
Exterior diameter of the barrel	At the muzzle	do	.591
	At the junction with the breech	do	.787
	At the fore end of the breech	do	1.102
	At the rear end of same	do	1.181
Grooves	Pitch	inches	9.45
	Depth	inch	.0059
Diameter of entrance to chamber	Minimum	do	.546
	Maximum	do	.555
Magazine	Total length	inches	26.28
	Interior diameter	inch	.669
Weight	Of the rifle without bayonet, magazine empty	pounds	9.196
	Of the rifle without bayonent, magazine containing eight cartridges	do	9.713
	Of the sword bayonet without scabbard	pound	.88
	Of the sword bayonet with scabbard	pounds	1.32
Sight graduation		yards	2187

The bullet is of hardened lead coated with nickel. Length, 1.181 inch. Weight, 231.48 grains. The muzzle velocity is 2,194 foot-seconds. It is said that the bullet can pierce over 15 inches of oak at 220 yards. The powder is a secret compound of gun-cotton and collodion, which is said to produce no smoke, little noise, and a very slight recoil.

It is reported that a new cartridge has been invented which is superior to the 86 M. The explosive requires no metallic case. This reduces the weight 277 grains. At 100 metres (107 yards) the bullet is said to traverse .433 inch of iron.

Operation of the mechanism when using the piece as a single-fire rifle.—(See plate.)—The carrier A is raised, and closes the magazine. The milled button of the locking lever is in the front recess of its lodgment.

The piece has just been fired, and the breech is closed. To open the breech, turn the bolt lever P from right to left, and draw the bolt to the rear until the lower tenon of the movable head is stopped by the projection on the carrier lever. This operation cocks the piece and ejects the cartridge case.

On raising the bolt lever, the cylinder and movable head of the bolt at first move alone independently of the other parts. As soon as their movement of rotation begins the spiral side of the cocking groove acts on the spiral side of the quoin and tends to turn the cocking piece. But the cocking piece being unable to turn on account of its projection, which bears against the left side of the upper slit in the receiver, takes a retrograde movement; at the same time the firing spring is compressed between the bottom of its cylindrical cavity and the projection on the firing pin which follows the cocking piece in its retrograde movement. The rear notch passes the sear, and then the half-cock notch, which engages the sear for an instant if the rotation is slow. In this first part of the lever rotation the movement of the cocking piece to the rear is effected entirely by the action of the spiral side of the cocking groove.

Continuing to turn the bolt lever, the front re-enforce of the cylinder begins to bear against the disengagement curve (forming the front of the opening into the receiver) at the same time that the extremity of the screw-ejector is opposite the transverse slit in the cylinder. After this, the cylinder and the movable head must move to the rear at the same time that they rotate. The movable head carries the extractor with it to the rear, and the extractor carries with it the empty cartridge case.

When the bolt lever is vertical the front face of the cocking piece has passed the sear, and the piece is cocked.

The bolt is now pulled to the rear until the lower tenon of the movable head fetches up against the projection on the carrier lever. The cartridge case is drawn to the rear, its left side takes against the screw-ejector, its right side is held by the claw of the extractor, consequently it pivots about the screw-ejector, and is projected out of the receiver.

A cartridge is next inserted in the chamber.

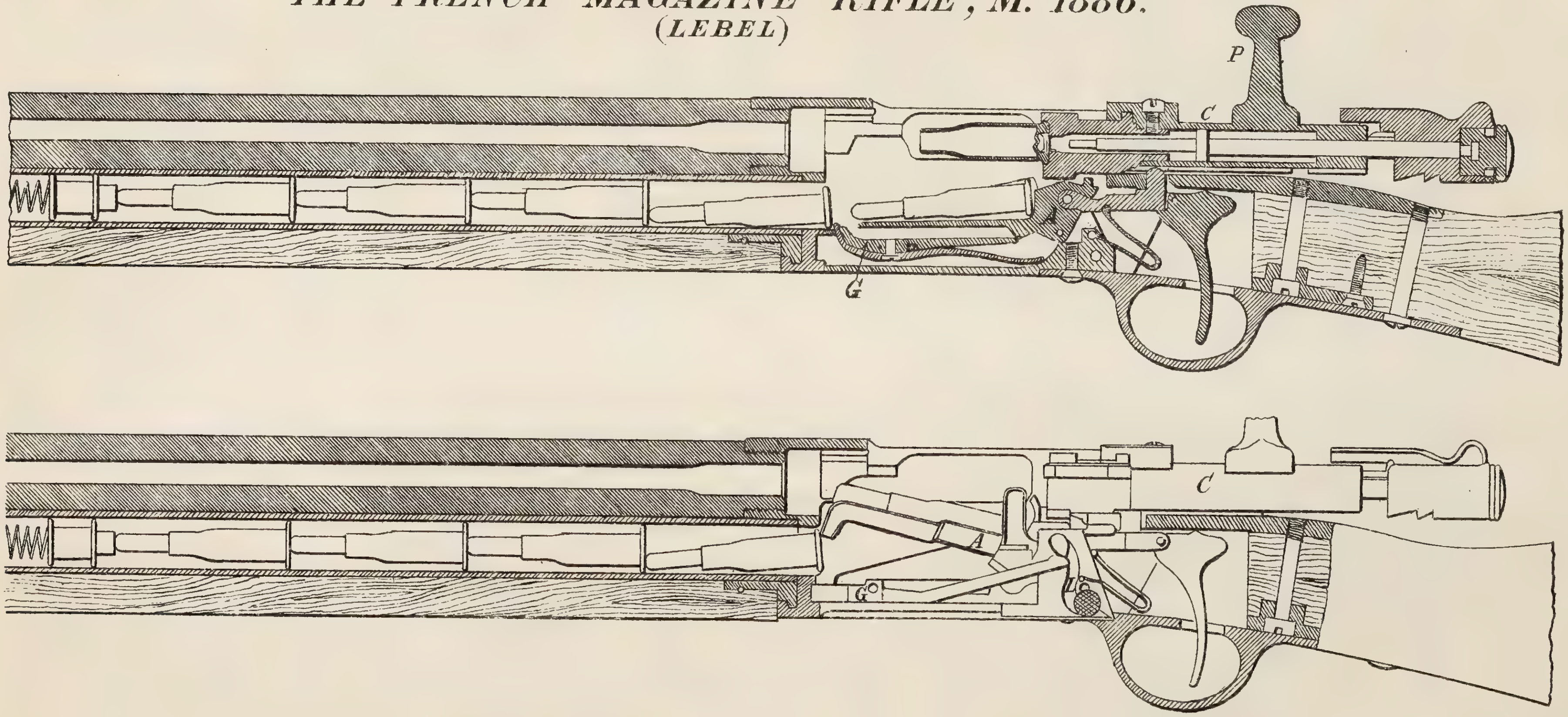
To close the breech, shove the bolt to the front and turn the lever down as far as it will go to the right.

During this movement the different parts operate as follows: The front of the extractor claw shoves home the cartridge if not done already. If the cartridge was placed in the hollow of the carrier, the front face of the movable head begins the movement of insertion. When the front re-enforce of the cylinder reaches the front side of the receiver the transverse groove is in position to receive the extremity of the screw-ejector; the cylinder can now advance only by turning at the same time, which causes a gradual movement of the bolt to the front, thereby reducing the chances of premature explosion, and in that event the ejection of the bolt to the rear would be prevented by the abutment of the rear re-enforce of the cylinder against the side of the receiver, and also by the abutment of the tenons of the movable head against the rear side of their lodgment.

In the first part of the rotation to the right the quoin is released from the cock-notch, the front face of the cocking piece advances about a millimetre, when it takes against the sear. Continuing the movement of the bolt lever to the limit, the tenons of the movable head are brought to bear against the rear side of their lodgment, the cylinder has compressed the spring, the cocking groove is opposite the quoin, the movable head is home, and the claw of the extractor is clear of the cartridge rim.

Operation of the mechanism when using the piece as a magazine rifle.—The operation of parts already described will be repeated only in connection with the repeating mechanism.

THE FRENCH MAGAZINE RIFLE, M. 1886.
(LEBEL)



The milled-head button of the locking mechanism is placed in the rear recess of its lodgment; the magazine is charged.

It is supposed that the rifle has just been discharged, that the breech is closed, the empty case is in the chamber, the carrier is down, and held in that position by the cartridge-retention lever G and the pressure of the lower re-enforce of the cylinder against the projection of the carrier lever. The first cartridge from the magazine has passed the lip of the retention lever, and is entirely in the carrier; the lip of the retention lever is raised by the pressure of the heel of the carrier against the end of the lever and stops the second cartridge.

On withdrawing the bolt, the lower tenon of the movable head strikes the projection for raising the carrier, and at the same time the empty case is extracted and ejected. The tenon striking against the projection on the carrier causes the carrier to turn about its axis. In its rotation the heel of the carrier slides along the inclined plane formed by the long arm of the cartridge-retention lever, clears it, and under the combined action of the tenon of the movable head and the retention-lever spring the carrier rises quickly with the cartridge it contains to the chamber.

The spring of the cartridge-retention lever, being freed by this movement of the carrier, acts on the long arm of the lever, causing the short arm to descend, thereby lowering the retention lip entirely below the rim of the second cartridge. This cartridge, yielding to the pressure of the magazine spring, moves to the rear until stopped by the beak at the fore end of the carrier.

On shoving the bolt to the front the cartridge is pushed into the chamber by the movable head and the extractor. The bolt-lever is now turned down to the right. The tail of the carrier-lever, owing to the pressure of the lower reinforce of the cylinder, descends, lowering the carrier. The heel of the carrier bears on the long arm of the cartridge-retention lever, and consequently raises the short arm and the lip. The second cartridge, being no longer withheld by the beak of the carrier, shoots into the carrier under the pressure of the magazine spring, and the rim of the third cartridge is intercepted by the lip of the retention lever.

The Rivista Marittima of October, 1888, quotes the following account of a trial near St. Cyr to determine the relative merits of the Lebel and Gras rifles in target practice. A company was armed with the Lebel and a company with the Gras rifle. At 400 metres (437 yards) the former made 180 hits in 200 shots and the latter only 80 hits under the same conditions. The firing with the Lebel was completed in forty seconds, without noise and without smoke. Its competitor produced a dense cloud of smoke, which interfered with the accuracy of aim.

Experiments were made by the French Academy of Medicine to determine the wounding effects of the bullet. Twenty corpses were placed standing at ranges of 218, 434, 656, 1,093, 1,531, 1,749, and 2,187 yards.

The apertures were very small, and the cure of the wounds would have been difficult. At less than 328 yards the bullet made very large flesh wounds which would have proved almost incurable, and produced typical lesions on the bones similar to those caused by the .433 Gras bullet, but fractures were less frequent. The Lebel bullet passes through the bone when it strikes full, and produces fracture only when the impact is tangential. It is liable to deformation only at long ranges; the bullet does not flatten entirely; the lead forms in small points on the surface, and these points remain in the wound, rendering its treatment more complicated.

The Revue du Cercle Militaire of June 2, 1889, quotes from the Mémorial de l'Artillerie de la Marine the following account of experiments made at Gavre in 1887 and 1888 to determine the penetration of the 86 M.

The ranges were 10 metres (32.8 feet), 200 metres (656 feet), and 500 metres (1,640 feet), normal to the targets and at 30 and 45 degrees.

Material.	Penetration (in inches).		
	At 32 feet.	At 656 feet.	At 1,640 feet.
Coal in bricks..	8.6	11.8	15.7
Coal in lumps ..	3.9	5.9	11.8
Sand	4.3	17.7	15.7
Earth	9.8	17.7	15.7

At 32 feet coal, sand, and earth offer very great resistance to penetration, and the bullets are considerably deformed by impact. The penetration increases with the distance; at 656 feet it is greatest, and the bullets are not deformed; at 1,640 feet the penetration is generally less. In brief, up to a certain range the penetration is diminished by the shock of impact. This peculiar result is probably also due to the irregular rotation of the bullet at the beginning of the trajectory.

In the following experiments, however, using other materials, the penetration increased with the shock of impact:

Material.	Penetration (in inches).			
	At 32 feet.	At 131 feet.	At 656 feet.	At 1,640 feet.
Fir.............	35.4	....	23.6	19.7
Oak	7.8	....	11.	5.9
Iron............	.47	....	.236	.157
Soft steel.......	.39	.354	.157	.0788
Chrome steel...	....	.1576	....	....

GERMANY.

The Revue d'Artillerie of November, 1888, quotes from the Allgemeine Schweizerische Militär-Zeitung the statement that the Minister of War has decided on arming the Infantry with a magazine rifle .2953 inch bore (7.5 ^{mm}).

The Revue d'Artillerie of April, 1889, quotes from the Vedette that the German Government has ordered from the manufactory at Steyr 400,000 rifles of the Mannlicher system; 250,000 of these are to be delivered before the end of 1890. To meet the demand for increased product, a branch manufactory has been established in Vienna. According to report, the new German arm does not differ from the Austrian system, except in some slight modifications, the most important of which is a device for doing away with the projection of the magazine until the moment of firing, which will enable the piece to be carried more easily on the shoulder. The charge is said to be of Duttenhofer powder, which gives a velocity of about 1,900 f. s. The product of this arm by the Prussian manufactories of Spandau, Danzig, and Erfurt is estimated at 50,000 per month.

ITALY.

The Vetterli-Vitali magazine rifle is supplied to the Infantry. It is a .407 bore and carries a magazine containing 12 rounds.

Length of rifle	inches..	53.1
Length of bayonet	do....	25.4
Length of barrel..	do....	33.9

Length of rifling	inches	31.5
Weight of rifle	pounds	9.614
Weight of bayonet	do	1.276
Weight of bullet	grains	308
Weight of charge	do	64
Number of grooves		4
Width of same	inch	.1576
Depth of same	do	.00788
Pitch	inches	25.98
Muzzle velocity	foot-seconds	1,584

The rifle supplied to the Navy is the 82 M., which has the following dimensions and weights:

Length of rifle	inches	48
Weight of same	pounds	9.02
Weight of charge	grains	61.7
Weight of bullet	do	308
Muzzle velocity	foot-seconds	1,394

The adoption of a smaller calibre is said to be under consideration.

PORTUGAL.

The 8mm (.315 inch) 86 M. Kropatschek magazine rifle is supplied to the Infantry and Cavalry. The dimensions and weights of the Infantry arm are as follows:

Length	Of rifle	inches	52
	Of sword-bayonet	do	18.5
Weight	Of rifle, magazine empty	pounds	10
	Of rifle, magazine containing 9 cartridges	do	10.59
	Of sword-bayonet	do	1.21
	Of scabbard of same	do	.572
Grooves	Number		4
	Pitch	inches	11
	Width	inch	.1576
	Depth	do	.0039
Ammunition	Weight of compressed lead bullet with thin copper envelope	grains	246
	Weight of charge	do	69
	Weight of round	do	543
	Diameter of bullet	inch	.315
	Length of bullet	do	1.26
	Length of round	do	3.22
Rapidity of fire	Single fire, aiming	per minute	10
	Single fire, without aiming	do	20
	Magazine, aiming	do	15
	Magazine, without aiming	do	30
Muzzle velocity		feet	1,745

The rapidity of fire means the rate of discharge, supposing the magazine continually filled. In reality, as thirteen seconds are required to load the magazine and thirty-six seconds to fire nine rounds, taking aim each time, the actual rapidity of fire is eleven per minute.

Velocity of recoil, 6.56 to 6.98 foot-seconds.

The breech mechanism operated perfectly in the ten rifles, from which two thousand five hundred shots were fired.

The sight is graduated to 2,187 yards.

The carbine used by the Cavalry is different from the above in the following respects:

Capacity of magazine	cartridges	7
Weight of carbine, magazine empty	pounds	8.8
Same, magazine filled	do	9.34
Sight graduation	yards	1,640

The naval rifle is the same as that supplied to the Infantry except for a modification of the stock invented by Sergeant Alvaro Antonio of the Navy. Three thousand Kropatschek rifles with this modification have been issued to the service.

SPAIN.

The rifle used is a 43-calibre Remington with an ammunition modified by MM. Freyre and Brull. The shape of the bullet only is altered. Around the base there is a projection .01578 to .0197 inch high and 02364 inch long. The bottom of the bullet is hollowed to receive a lubricant consisting of wax containing 3 per cent. of glycerine. The powder is manufactured in Grenada.

Weight of charge	grains	81
Weight of round	do	678
Weight of bullet	do	447
Length of round	inches	2.98
Length of bullet	do	1.29
Muzzle velocity	foot-seconds	1,443

TURKEY.

The Revue du Cercle Militaire of January 20, 1889, quotes from the Allgemeine Militär-Zeitung the following information regarding the magazine rifle lately adopted by the Turkish Government. This rifle is manufactured at the Oberndorf Works on the Neckar, and, except for some slight modifications, is similar to the German repeating 71–84 M. The ballistics are very satisfactory. The trajectory is flat and up to 400 yards does not exceed the height of a man.

Weight of rifle	pounds	9.35
Calibre	inch	.374
Weight of bullet	grains	283.9
Weight of charge	do	69.4

The bullet is an alloy of lead and tin. The powder used is Rottweil-Hamburg. At 2,840 yards the penetration in pine is said to be 1.96 inches.

EXPLOSIVES.

EMMENSITE.

In January, 1888, letters-patent were granted to Dr. Stephen H. Emmens, of New York, for a new organic acid discovered by him, to which the name of Emmens acid has been given, and the compounds formed with this acid bear the general name of emmensite.

The acid was at first obtained by dissolving at a gentle heat an excess of commercial picric acid in concentrated fuming nitric acid (50° to 52° C.).* This operation is effected without danger, as the mixture is refrigerating. The solution, on evaporation, deposits rhomboidal prisms of a fine yellow color, which are the new acid. Subsequent researches have led to a cheaper method of preparation, of which, however, no particulars are given.

It is doubtful if any one of the published processes of manufacture of the various compounds known as emmensite represent the true one, and it is therefore hardly worth while to reproduce them. The statements following are indorsed by the inventor. They are necessarily disconnected, as they are gathered from many sources.

Emmensite in its simplest form consists of two ingredients, one of them being a new nitro-derivative of certain hydrocarbons of the aromatic series, which can be prepared by the distillation of coal at a low temperature, whilst the other is a mineral salt. For special purposes other chemical ingredients may be added, but the general character of compound remains the same in all cases. The ingredients are mixed together by a process which forms one of the principal features of the invention, and the resulting product is a true chemical compound (not a merely mechanical mixture), which appears in the form of a solid cake or mass, and may be granulated, by which means it is possible to retard or accelerate the explosive action by increasing or diminishing the size of grain.

---

*The "A" explosive, the use of which as a bursting charge for shell caused the bursting of the South Boston gun, was a solution made as here described.

There are four grades of the compound, viz, Nos. 1, 2, 3, and 4. No. 1, when heated, melts into a resinous body without detonating; a match ignites it with great difficulty. Nos. 3 and 4, if very quickly heated to a high point, may be caused to explode feebly; they will, moreover, burn violently if ignited.

By placing emmensite on an anvil and striking with a *glancing* blow the particles immediately in contact with the hammer may be caused to explode, but the detonation thus produced is of a feeble character and is not propagated throughout the mass of the explosive. The same phenomenon is observable when a quantity of emmensite placed on an iron plate is struck with a bullet from a pistol or rifle.

The explosion of emmensite of the highest grade is free from smoke, and the quantity resulting from the lower grades is trifling compared with that due to ordinary gunpowder.

Fired from a Springfield rifle, 25 grains of emmensite do more work on the projectile than 70 grains of ordinary gunpowder, and without giving rise to abnormal pressures. Cartridges of emmensite, *i. e.*, emmensite packed in paraffined paper cases, have been fired as projectiles from a 1-inch smooth-bore gun without premature explosion. The compound has also been used as a propelling charge in the same gun with better results than those obtained with gunpowder.

In response to a letter from this office making inquiries relative to the stability of his explosive, Dr. Emmens writes as follows: "The only experiment I have made to determine the keeping properties of emmensite has been to actually make and keep the powder, marking the various samples with the date of manufacture, and then testing them from time to time. Proceeding in this way, I have not noticed any appreciable change in *two years*."

And he adds: "I am aware that a popular impression exists as to powders of the picric and picrate classes being unstable; but I have never yet met with any explanation of *why* such instability should characterize the powders in question. The idea is a popular error, akin to that * * * respecting the liability of picric acid to explode when heated."

The specific gravity of emmensite is stated to be 1.8, and its explosive power is estimated at 283 tons per square inch.

PICRIC ACID AND THE PICRATES.

Apropos of the question of the explosive properties of picric acid, the following observations by Sir F. Abel, C. B., F. R. S., chemist to the British War Department, are quoted. The observations are the result of a series of experiments conducted at Woolwich about two years since:

If freely or partly exposed picric acid is continuously exposed to heat the material fuses, ignites, and burns with a smoky flame. The experiments made in this direction are simply confirmatory of the results of other observers, and there appears no doubt that picric acid burns away harmlessly, even if exposed to heat, in very much larger quantities than those employed in the Woolwich experiments. (Instances have been cited in which as much as 5 cwt. of picric acid, packed in bulk in a dry, wooden cask and exposed to fire, has burned away without explosion.)

If picric acid be very strongly confined and exposed to sufficient heat, its decomposition will eventually ensue, and will be attended with explosive results. There is no doubt, however, that the simple application of flame, or a white-hot body, for a brief period, to picric acid under these conditions does not suffice to develop its explosion, and that to attain this object special exploding or detonating appliances (of the character used with other high explosives in shells) must be employed for the purpose of initiating a detonation in some part of the charge.

Other conclusions drawn from these experiments are stated by Col. Majendie H. M., chief inspector of explosives, as follows:

(1) Dry picric acid may be perfectly detonated by means of a 5-grain fulminate detonator; (2) the detonation of a small quantity of dry picric acid is capable of detonating a quantity of picric acid placed at a short distance from it; and (3) the detonation of picric acid containing, at any rate, as much as about 17 per cent. of water may be effected by detonating a charge of dry picric acid alongside it.

It is believed that these observations will be of interest, if for no other reason than that both in France and England these properties of picric acid have been utilized in the explosive known as melinite in the former and lyddite in the latter country.

Concerning the picrates, Sir F. Abel's observations are again quoted:

Combinations of picric acid with the metals possess the property of exploding or detonating when subjected to the action of heat of sufficient intensity or duration. The application of friction or percussion also develops detonation. The picrates of potassium and of lead are among the most sensitive of these compounds.

The detonation of a picrate, such as the picrate of lead, of potassium, of calcium, or of strontium, will develop the detonation of picric acid, if it takes place in contact or close proximity (according to the scale upon which the initiative detonation occurs).

BELLITE.

In February of the present year some further experiments with bellite (see No. VII, p. 373) were made in England, which, from the account given in Engineering, seem to indicate complete safety attending its use, and also its adaptability to certain military purposes.

The first experiment was intended to exemplify the use of the explosive in submarine mining; a charge of 1.5 pounds was inclosed in a tin canister, and on being fired with a detonator the explosion sent the spray fully 150 feet high.

The following were made with the object of showing the perfect safety of the material, and that it could be fired only by a detonator: A bellite cartridge was broken in two, and one-half thrown on a fire, where it slowly burnt away with a reddish flame; the other half, weighing about 2 ounces, was then exploded on a wrought-iron plate 12 inches by 12 inches by three-eighths inch thick, the charge being tamped with clay. The shock bulged the plate to a depth of about 2 inches, but did not pierce it. An even more convincing proof of its safety was afforded by the chairman of the company, who, holding part of a naked bellite cartridge in one hand, applied a lighted fuse to the fragment with the other; the bellite charred and smoldered, but went out immediately on removing the match. An iron weight, weighing 120 pounds, was dropped from a height of 18 feet on to a number of naked bellite cartridges supported on an iron plate. The test was repeated twice, as on the first occasion the weight fell somewhat to one side, but on the second trial, with more careful centring, the mass of bellite was crushed to a powder. A small canister capable of holding 5 ounces was then filled with the fragments resulting from the last experiment, and laid on the web of an old Great Eastern Railway Company's steel-faced rail, the charge being slightly tamped with clay. On firing, the rail was snapped in two, a piece about 1 foot long being flung 6 yards, and smaller fragments much farther, whilst a pit 15 inches deep was sunk in the ground immediately underneath the position of the charge. A fragment of bellite was fired from a large calibre gun (No. 8) with 2 drachms of powder against an iron plate, without any explosion of the bellite occurring either in the bore of the gun or on striking the target.

To compare the effects of bellite with those of dynamite, 2 ounces of each explosive were fired on wrought-iron plates measuring 12 inches by 12 inches by three-eighths inch thick, each plate, with the object of rendering the conditions as uniform as possible, being supported above the ground by a narrow cast-iron ring about five-sixteenths inch thick, 3 inches high, and 11 inches internal diameter, the charge in each case being tamped with clay. Both plates were pierced through, but the rents in the one on which the dynamite had been fired were considerably larger, whilst, on the other hand, the bulge in this plate was only 2.5 inches deep as compared with 3 inches in the case of the other, thus showing the action of the dynamite to be more local.

The next series of experiments was made with a view to show the adaptability of bellite to military purposes. To this end the ballistic properties of bellite and Curtis and Harvey's rifle-powder were first compared, a 6-inch ball weighing 32 pounds being fired from a mortar first, with .5 ounces of powder, and, secondly, with .25 ounces of bellite, the weighings being carefully made in the presence of two representatives of the press. With the powder the ball was thrown a distance of 40 yards 1 foot, and with the bellite to a distance of upwards of 100 yards, the penetration into the ground being also much greater in this case. A charge of 8 pounds of bellite was fired under a length of railway with the result that both rails were smashed clean through, and portions of the sleepers thrown to a distance of 40 yards.

It may be noted in connection with the above that the company having control of the manufacture of bellite has devised a delay-action fuze to be employed with bellite when used as a bursting charge for shell. This invention has been purchased by the Swedish Government.

As now made, bellite consists of 5 parts by weight of ammonium nitrate and 1 part of dinitro-benzine. The saltpetre mentioned in No. VII as one of its constituents is omitted.

MELINITE.

L'Illustration of November 17 last says that the ingredients of which melinite is composed becoming scarce, the French are making a new explosive to take its place.

Engineering quotes a statement of the London correspondent of the New York World to the effect that the British Government has arrived at the conclusion that melinite is unsuitable for use in the tropics and will not keep long enough to be trustworthy even in Europe.

GERMAN PRISMATIC POWDERS, C. 86.

Krupp's report No. 73, October, 1888, gives the results obtained with the new powder submitted for trial by the United Rhenish Westphalian Powder Company. The following is an abstract of a notice of this report published in the Deutsche Heeres-Zeitung of February 9, 1889.

After long experiment the United Rhenish Westphalian Powder Company has succeeded in submitting a new powder, which not only does more work with less pressure than the old powders, but also possesses the property sought after for so many years—the production of but little smoke.

There are two varieties of the new powder, viz, (1) the coarse-grained cannon powder, G. G. P. C/86, for use with small calibres (4 to 8.7 cm.); (2) the prismatic powder, P. P. C/86, employed with medium calibres (10.5 to 25 cm.).

The first resembles in form, size of grain, and color, the coarse-grained powder formerly employed with field pieces; it has, however, a different composition, which gives it the following advantages: (1) more work per given weight of charge; (2) relatively small recoil; (3) a less quantity of smoke, which is, moreover, rapidly dissipated; (4) less flame at the muzzle of the gun. On the other hand, the new powder has the disadvantage of absorbing moisture more readily than the old, for which reason it must be packed in metal cases.

The results of some of the comparative tests of the powder are summarized in the subjoined table. The new powder appears first in each case.

Powder.	Gun.	Charge.	Projectile.	Muzzle velocity.	Pressure.
		Pounds.	*Pounds*	*Foot-seconds.*	*Tons.*
G. G. P. C/86	5^{cm}	1.32	3.8	1,991	13.6
Cubical R. 8.85		1.87		1,984	16.0
G. G. P. C/86	7.5^{cm} L/30	2.6	15.0	1,512	11.2
Cubical R. 8 85		3.3		1,486	13.7
G. G. P. C/86	7.5^{cm} L/40	4.4	15.0	1,929	13.9
10–13^{mm} H. 80		4.4		1,519	12.1
G. G. P. C/86	8.4^{cm}	3.1	15.4	1,745	14.2
Cubical R. 8.85		4.0		1,656	15.4

The following table shows that the powder burns with great uniformity, and that with proper care in packing its ballistic properties remain unaltered.

Date of firing.	Gun.	Charge.	Projectile.	No. of rounds.	Mean muzzle velocity.	Maximum differences.
		Pounds.	*Pounds.*		*Foot-seconds.*	*Foot-seconds.*
March 24, 1887	7.5^{cm}	3.0	12.1	5	1,633	+ 6.5 −23
May 24, 1887				5	1,633	+10 −10
January 8, 1888				10	1,637	+10 − 6.5

The foregoing experiments were made with the ordinary cartridge; with metallic-case cartridge the results are given as follows:

Date of firing.	Gun.	Charge.	Projectile.	No. of rounds.	Mean muzzle velocity.	Maximum differences.
		Pounds.	*Pounds.*		*Foot-seconds.*	*Foot-seconds.*
July 27, 1887	7.5^{cm}	2.6	15.0	11	1,594	+16 −13
March 2, 1888				5	1,591	+ 6.5 − 3
July 22, 1887	8.4^{cm}	3.1	15.4	10	1,699	+16 −13
July 27, 1887				10	1,706	+13 ....

The results obtained with the new prismatic powder, P. P. C/86, and the comparisons made with the old powder P. P. C/82, may be summarized as follows:

Powder.	Gun.	Charge.	Projectile.	Muzzle velocity.	Pressure.
		Pounds.	*Pounds.*	*Foot-seconds.*	*Tons.*
P. P. C/86 10–15^{cm}	10.5^{cm}	8.6	39.7	1.729	12 8
P. P. C/82 10–15^{cm}		10.4		1,637	13.6
P. P. C/86 10–15^{cm}	15^{cm} L/30	17.6	86.0	1,660	11.3
P. P. C/82 10–15^{cm}		22.0		1,670	13.4
P. P. C/86 15–20^{cm}	15^{cm} L/35	34.2	112.4	1,945	15.4
P. P. C/82		51.8		1,942	16.7

HENGST POWDER.

Under this name has appeared a new explosive, of which the following account is drawn from Engineering:

The new powder is prepared from straw, which is pulverized, chemically treated, and prepared in granular form for use. It is claimed for it that it is smokeless, flameless, practically non-fouling and non-heating, and that both the recoil and the report are less than those of black powder. The powder has recently been tested by Mr. P. F. Nursey, C. E., the experiments being made comparative with ordinary gunpowder. The firing was from an English pattern Martini-Henry rifle, the charge in one case being 85 grains of rifle fine-grain powder, and in the other 35 grains of Hengst powder, the cartridges in other respects being alike. The results showed the velocities due to the Hengst powder to be somewhat lower than those due to its competitor, but in this respect a grain or two more of the Hengst explosive would doubtless have placed the two on a level.

MAXIM POWDER.

The London Times of March 23 contains a notice of a then recent competitive trial between ordinary black powder and the Maxim smokeless powder.

The firing, it is judged from the context, was from a Maxim automatic machine gun, .45 bore. The charge of black powder was 85 grains to the cartridge, while that of the Maxim powder was only 55 grains; yet, with the latter, a slightly increased velocity was obtained. The noticeable point, however, was the comparatively small amount of smoke produced by the Maxim powder. After some thirty rounds with the black powder it was impossible to see the target, while with its competitor the target was clearly discernible throughout a series of fifty rounds, the powder causing only a faint mist. The atmosphere was clear, and there was a light air. It is said that at a distance of 600 yards it would be almost impossible to fix the position of the firing line from the smoke indications, and at that distance also the report would be scarcely audible.

Another advantage claimed for this powder is that if wetted it regains its efficiency after drying.

LEBEL POWDER.

The Rivista di Artiglieria e Genio, quoting from the Revista Científico-Militar, says: It is now known that the Lebel powder is a nitrous compound similar to pyroxilin, and that it deteriorates so rapidly that the marvelous results claimed for it can be obtained only with cartridges newly made—with powder only a few months old the initial velocity falls off notably. In consequence of this the French have abandoned it in favor of an ordinary black powder.

The report adds that under these circumstances the Lebel rifle will be in no wise superior to the Austrian Männlicher or the Portuguese Kropatschek; it will be simply a good 8^{mm} small arm, capable of firing a ball of 230 to 280 grains weight with a velocity of about 1,800 foot-seconds.

OTHER SMALL-ARM POWDERS.

According to the Belgian journals the Royal gun-powder factory at Wetteren, Belgium, has succeeded in producing a variety of powder equal in all respects to the Lebel powder. This new product has received the name of paper powder, and is said to be remarkable for a complete absence of fouling.

It is stated that the Belgian Government has accepted the Wetteren paper powder for new magazine rifles, and that an initial velocity of 2,378 foot-seconds has been obtained with it. It is, however, believed desirable to reduce this velocity to 1,968 foot-seconds, in order to reduce the work upon the piece. The charge necessary to produce this velocity is but 45 grains with a bullet of 216 grains; the corresponding pressure is about 7 or 8 tons to the square inch. The powder is said to possess great stability, to be smokeless, to give high velocity, and to be not injurious to the bore.

The Italian Government also claims to have produced a successful rival of the Lebel explosive.

The Militär Zeitung states that the German Minister of War has concluded contracts with Rottweil-Hamburg and the United Rhenish-Westphalia Powder Companies for the delivery within a short time of a smokeless powder for the new small-bore rifle.

About the beginning of the year experiments were made in France with a new powder, which, when fired from the Gras rifle, gave a velocity of 1,900 foot-seconds, as compared with 1,475 foot-seconds due to the old powder, the charge in the former case being only 60 per cent. of that in the latter. The new powder is said to be smokeless and not to be affected by damp.

It is reported by the Army and Navy Gazette, May 25, that Captain Noble, of the Elswick firm, has produced a new powder which seems reliable and is practically smokeless and noiseless on explosion. It is to be tried by the War office at Lydd, and will probably be adopted for small-arms and, in a modified form, for R. F. guns. It is said to be of a "curious, grayish material in long threads, or whip-cord like form, presumably from the shape it assumes under hydraulic pressure." At 300 yards distance it is not heard, and but a faint haze is seen when a volley is fired.

HIGH-EXPLOSIVE PROJECTILES.

Experiments with the Zalinski high-explosive projectile are described on page 386 *et seq.*

"RESISTANCE" EXPERIMENTS.

During the past twelve months a number of experiments have been made in England to test the relative explosive effects of shells charged with gunpowder, gun-cotton, and lyddite (an English form of melinite), and also to determine the amount and distribution of armor to be used on the vessels proposed in the new ship-building programme. [Attention is called to the new designs of English ships described in Chapter III, which may be taken to indicate the present position of the Admiralty on this question]. The target for both purposes was the old armored vessel *Resistance,* having seven-eighths-inch iron skin plating, 4½-inch wrought-iron armor on the sides amidship for a length of 143 feet, and two thwartship 4½-inch wrought-iron bulkheads, for protection against raking fire.

The results of the experiments have been closely guarded, and no official statement of them has as yet appeared. The only particulars to be given, therefore, are those gathered from the professional journals, chiefly from the English service papers and the London Times.

The firing of July 13, 1888, was from a 6-inch 5-ton gun, using a 42-pound powder charge and 100-pound projectile. Five rounds had been fired when a badly aimed shot carried away one of the ship's moorings, and the firing was discontinued. The only matter of importance brought to light is the fact that the melinite used on the occasion was too sensitive, the shell breaking up against even the unprotected portions of the ship's sides—in other words, against seven-eighths-inch iron plating. The powder-shells are said to have inflicted the most damage.

Firing was resumed on the 20th September with an 8-inch 14-ton gun, but of the results nothing is known except that "they were such as to create a strong current of professional opinion in favor of an increase of the extent of protection."

The final and most extensive series of experiments was made on March 13, 1889. The *Resistance* had meantime been fitted with a steel protective deck, and two five-eighths-inch steel thwartship bulkheads, the forward one just abaft the engine-room, and the other about 16 feet farther aft, the space between them being closely packed with coal. The ship's stern-post was knocked out to permit a free fore-and-aft fire. Casemates, formed of 2-inch steel plates on the outside and 4-inch plates on the inside of the seven-eighths-inch skin, were erected, their position being indicated on the outside as targets upon which to direct the fire, which was delivered from the gunboats *Kite* and *Blazer*, anchored off the stern and starboard side of the target. Four 6-inch shell were fired by each vessel, half being charged with gun-powder and half with melinite.

The United Service Gazette speaks of the results as follows: "Briefly, the result may be said to have been the annihilation of the upper works of the ship; but, analyzing the destruction worked by the lyddite (melinite) as compared with shells filled with slow-burning gun powder, the former was found to be too highly sensitive, exploding immediately on impact against the sides of the vessel, instead of, like the missiles filled with ordinary gun powder, bursting within the ship. Succinctly speaking, the lyddite shell made a splodge on the face of the target, and beyond that did little or no injury; the gunpowder shell, on the contrary, made a clean breach through all obstacles and exploded between decks, spreading ruin and destruction around. The gunboats had riven the steel casemates to ribbons, and rendered *hors de combat* the wooden dummies, while the turtle-back steel deck was completely riddled by fragments of broken projectile, some of which not only penetrated the transverse bulkheads built up abaft the engine-room and knocked all the coal in the bunkers to the semblance of pulverized charcoal, but found a clear passage through the ship fore and aft."

The attack was resumed on the following day, the 14th, with guns of 9-inch calibre; but the results are not given with sufficient detail to be of value. Professional journals, however, report the effect of explosions of 9-inch shell fired against targets or casemates representing, first, coal-bunkers intended for protection, and, second, the armor protection for secondary battery of the *Nile* and *Trafalgar*, and conclude that these will give good protection against the fire of guns of 6-inch calibre, and less, at reasonable distances, but that the effect of the shell fire at 100 yards range was most destructive and remarkable.

The Journal above quoted says, elsewhere: "The officers of the *Excellent* made a careful inspection of the damage sustained (by the *Resistance*), more especially with reference to the steel protective deck as well as the steel mantled shields of the same pattern as those used for sheltering the men working the guns of a vessel armed *en barbette* or fitted with central pivot guns in sponsons. According to naval experts the artillerists had all the best of the encounter, and the ship builders are nowhere as opposed, at least, to shells filled with gunpowder. And, judging by what was said subsequently, the visitors were of like opinion."

SMOLIANINOFF SHELL.

In June, 1888, at Annapolis, Md., three shells loaded with the Smolianinoff explosive (see No. VII, p. 378) were fired from the service 8-inch M. L. R. The shells were not fuzed.

The first two did not explode at all; the third exploded on impact with the water. As this explosion was quite unexpected by the inventor it was thought to throw much doubt upon the safety of his mixture.

MELINITE SHELL.

According to Iron two-thirds of the bursting charge of melinite shell is cresilite, which is said to increase materially the powers of the melinite, while at the same time it contributes to its preservation and safety in handling. The process of filling the shell is supposed to be a secret, but it has been learned that the cresilite, a hard, gummy substance, is first melted in copper vessels and then poured into the shell, occupying about two-thirds of the interior; the remaining space is filled up with melinite, rammed in by means of a mallet, a work that requires the utmost delicacy to avoid accident.

The following quotation is from the London Engineering: "A course of experiments was recently conducted at the camp at Chalons in the presence of M. de Freycinet and the heads of the Paris military commission, with the object of ascertaining the relative resisting powers of armor-plate and concrete-faced cupolas against melinite shells. The trials demonstrated that the shelter afforded by a layer of concrete 10 feet thick is greater than that of iron-protected metal plates, but in justice to the latter it must be mentioned that the armored cupolas had already withstood five months of almost daily exposure to the heaviest shot and shell that could be directed against them. It was, however, concluded that the concrete facings were superior to the plain metal shields, and the two combined afforded almost perfect protection against melinite, whilst the metal alone showed an unexpected degree of resistance to the attacks with this explosive, fired in some instances at point-blank range. Some of the shells contained 197 pounds of melinite. Nevertheless, in spite of their battered plates and other damages, the two guns inside the cupolas were found serviceable and readily workable to the last, and the gunners could have maintained their positions at the pieces during the whole trial."

Some further particulars of the *Belliqueuse* experiments referred to in last year's number have recently been made public in Le Yacht and are given herewith.

The fire directed against the *Belliqueuse* was from 14 and 16^{cm} guns of the 1881 model, throwing shell of 66 and 99 pounds weight, charged, respectively, with 6.2 and 8.8 pounds of melinite.

It will be remembered that the effect of the shell striking against the armored portion (4¾ to 5⅞ inches of wrought-iron) of the ship's side was stated in No. VII, to be practically nil, the points of impact being marked by only slight indentation. The shell that struck the unarmored portions most frequently burst after perforation, although sometimes the explosion occurred in the side. Fragments of shell weighing from one-third to one and a half ounces, and which sometimes numbered as many as 1,500, were thrown with great violence in all directions, destroying the entire personnel (sheep and dummies probably) not under protection. To these results should be added the local effect of the explosion; if this took place in the ship's side it frequently made a clean hole some 5 feet in diameter; when it occurred inboard it broke the deck beams and caved in the decks and shattered every bulk-head in the vicinity. Of the twelve shell fired, the explosion in three cases set the ship on fire.

GUN-COTTON SHELL.

The following notes on gun-cotton shell form a natural sequel to last year's summary and are mainly from the same source, the Revue d'Artillerie.

The gun-cotton prepared at Walsrode as a bursting charge for shell contains about 20 per cent. of moisture, and is compressed either in the form of parallelopiped grains measuring 0.40 to 0.70 inch on the sides and 1 to 1.5-inch in height, or in thin circular discs. It has been stated that the preserving process devised by Mr. von Förster, the director of the Walsrode factory, consists in steeping the wet cotton in ether for fifteen to twenty seconds, by which means there is formed a hard surface film, which, while it is not absolutely impervious to water, maintains a nearly uniform degree of humidity. After loading the shell, melted paraffine is poured over the charge, and on cooling, forms with it a solid mass. The film formed over the gun-cotton grains by their partial solution in the ether stops the entrance of the paraffine effectually.

Thus prepared the cotton may be used with common, battering, and torpedo shell. The battering shell is represented (see Fig. 1) as fitted with a base fuze devised by Mr. von Förster, of which, however, only meagre details are given. The separate parts of which it is composed are said to be so arranged that, should the fuze detonate prematurely, the detnoation can not communicate itself to the charge; impact, however, causes a displacement of the parts, and the detonation of the wet cotton is then readily effected. The fuze is constructed on the delayed action principle and the delay can be regulated at will. Common shell are fitted with a nose fuze of design similar to that just described; torpedo shell (see Fig. 2) may be fitted with either base or nose fuze.

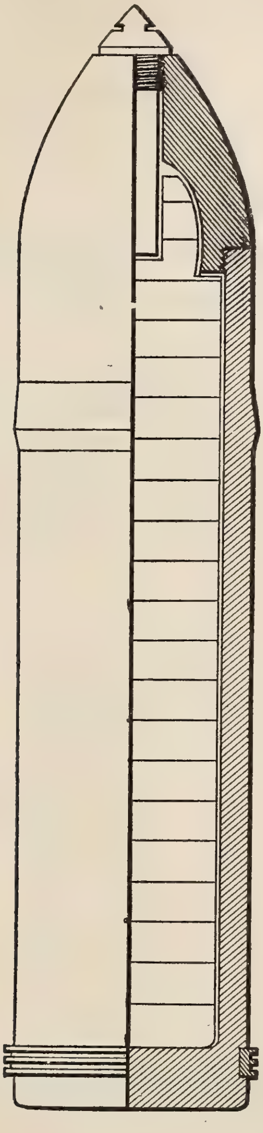


Fig.1.

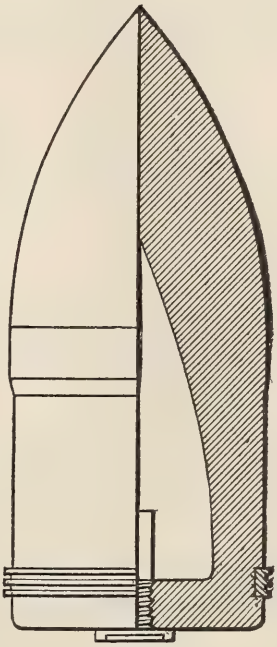


Fig.2.

The experiments described were executed in Italy, Austria, and Germany.

The object of the first series made in Italy was to test the safety of firing gun-cotton shell from service guns, with approximately the usual muzzle velocities. The conditions and results of the firing are summarized in the following table:

Gun.	Weight of projectile.	Bursting charge.	Initial velocity.	Range.	Remarks.
	Pounds.	*Pounds.*	*Foot-seconds.*	*Yards.*	
15^{cm}	66.1	3.1	1,312	5,470	With reduced charge.
15^{cm} mortar	66.1	3.1	682		
21^{cm} howitzer	176.4	8.2	820	4,375	
24^{cm} howitzer	244.7	15.4	758	4,375	
24^{cm} mortar	244.7	15.4	787		
28^{cm} howitzer	485.0	17.0	1,007	7,327	Cast-iron shell with solid head, base fuze.
21^{cm} howitzer		44.1		3,827	Topedo shell.

The conclusions drawn from this series are that the Walsrode method of charging shells is simple and practicable, and that no danger attends its employment.

The second series was for the purpose of determining the explosive effect of gun-cotton shell when fired into earth at comparatively high angles, and for purposes of comparison shell charged in the ordinary manner were also fired.

The subjoined table indicates some of the results obtained in the soft earth of San Maurizio:

Calibre.	Bursting charge.	Sphere of action.		
		Length.	Breadth.	Depth.
		Feet.	*Feet.*	*Feet.*
15^{cm}	Gun-cotton	10.5	7.2	3.9
	Powder	5.9	5.6	6.2
21^{cm}	Gun-cotton	11.8	11.1	7.5
	Powder	10.5	9.5	6.6
24^{cm}	Gun-cotton	15.4	15.4	6.6
28^{cm}	Gun-cotton	13.1	13.1	9.8
	Powder	13.1	13.1	6.6

A 21^{cm} torpedo shell, exploded while in a horizontal position at a depth of 4.1 feet beneath the surface, made a crater in the earth 18 feet in diameter by 7.9 feet in depth.

The third series was executed against a pontoon provided with a protective deck. After a few rounds with common shell from a 24 c. m. howitzer the pontoon was half submerged, and was saved from sinking only by her water-tight compartments. As the range, angle of fall, and thickness of the deck are not stated, the details of the results are of no value.

The account of the Austrian trials offers nothing calling for special notice, except that the velocity in some cases reached 1,560 foot-seconds.

The experiments made in Germany are those briefly quoted from the Deutsche Heeres Zeitung in last year's number. They are here given at length.

The firing was from a Krupp 21 c. m. gun, 22 calibres long. The shell were of Krupp steel, 2.5 calibres long, and weighed, when charged with 2.2 pounds of gun-cotton, 216 pounds; they were fitted with the Von Förster base fuse. The target was a compound plate measuring 7′.4 by 5′.6 by 4″.7, backed by 23″.6 of oak in two layers. About 18 feet in rear of the target was a stockade composed of pine timbers 9″.4 thick, which supported an embankment of earth 11′.5 thick at the base and 3′.3 thick at the summit.

The first round was with a blind shell and a 48.5 pound charge of prismatic brown powder, which gave to the projectile an initial velocity of about 1,395 foot-seconds. The shell perforated the plate, backing, stockade, and earth wall, passing through the latter at a point where it measured about 6.5 feet through. The second and succeeding projectiles were fused. The second one perforated the target, stockade, and earth wall and exploded in the air just as it emerged. The third exploded at a depth of about 6.5 feet in the earth wall, where it formed a crater 8.2 feet in diameter by 2.1 feet in depth. The fourth, fired with a 30.9-pound charge, produced the same effect as the third.

To prove that the fuse could not detonate the wet cotton charge except on impact, three cast-iron shell were placed in a trench and their fuses detonated; in no case did the shell charge explode, but the dry cotton contained in the fuses proved sufficient to burst two of the shell into fragments and to rupture the walls of the third one. These and other experiments of a similar nature lead the writer to make the statement that if at any time a fuse should detonate prematurely, the worst to occur would be a breaking up of the projectile and a slight injury to the bore.

C. E. VREELAND,
Lieutenant, U. S. Navy.

ARMOR.

The Portsmouth armor trials instituted last year for the purpose of determining the respective merits of compound and all-steel armor have been concluded, but, with the exception of a few published notes on the earlier trials and the advertising publications of some of the competitors, the results have been kept secret. It has been generally stated that the Cammell compound plate was the victor, but this statement merely proves that the English compound plate is better than the English steel plate: it does not determine the superiority of the compound type of armor, as it must be remembered that those submitting steel plates had had little or no experience in their fabrication.

CAMMELL COMPOUND PLATE.

[Taken from advertisement of Cammell & Company.]

The Cammell compound plate measured 8 by 6 feet by 10.5 inches. The percentage of carbon in the steel facing was between .9 and 1.00. The plate was secured to the backing by eight bolts. Three Holtzer 6-inch armor-piercing shell and two Palliser shells were fired from a 6-inch B. L. gun; the powder charge was 48 pounds; the muzzle velocity 1,976 f. s., and the striking energy 2,723 foot-tons. The range was 30 feet.

The first Holtzer shot, fired at an elevation 2 degrees, remained sticking in the plate, with its base projecting 6 inches, and its body much split. Four superficial cracks were produced by this shot, and when the plate was stripped from the backing, after the trial, its back showed a circular bulge 17 inches in diameter, projecting 1.8 inches and cracked through.

The second shot, also a Holtzer, fired at an elevation of nearly 6 degrees, stuck in the plate in the same manner as shot No. 1. Six superficial radial cracks were produced, and the back bulge, 18 inches in diameter, projected 2.3 inches and was badly cracked.

Nos. 3 and 4 shots, Palliser chilled cast-iron, were fired under conditions similar to Nos. 1 and 2. They indented the plate some few inches; the points stuck in the plate, but the bodies broke up completely. Three new fine cracks were produced and the back showed only an indication of bulges, although slightly cracked. Part of the base of No. 1 shot was shaken off.

No. 5 shot, another Holtzer, was fired at nearly 3 degrees elevation, and produced effects almost identical with those of No. 1, although the cracks were of more serious character. The remainder of base of No. 1 projectile was shaken off.

At the conclusion of the trial the plate was practically intact, though somewhat defaced, showing twenty-three cracks more or less serious, and bulged. The backing was practically uninjured, though slightly indented by shots 1, 2, and 5, and but two bolts were sheared or driven back. The plate showed itself to be of the highest quality.

CAMMELL STEEL PLATE.

The following report of this trial, which formed one of the Portsmouth series, is taken from the London Times:

The Cammell all-steel plate measured 8 by 6 feet by 10.5 inches. Five shots were discharged against it from the 6-inch gun at a 30-foot range. Two were chilled

Palliser projectiles, while the remainder were Holtzer solid forged-steel shot. The powder charge was 42 pounds, the muzzle velocity 1,920 feet per second, and the muzzle energy 2,556 foot-tons. The chilled shot were entirely broken up, but the indents in the plate were deeper than in the case of the compound plate. The steel projectiles were pointed diagonally across the face of the plate from the bottom right corner to the top left corner, the difference in the angle of impact having an important effect upon the ballistic value of the various rounds. The first shot, fired at the normal, penetrated the plate, the base being about 5 inches below the surface. The second shot, fired at an inclination of 8 degrees, buried itself in the target with the exception of 2.5 inches, while the third and last round, fired at an angle of 16 degrees with the normal, protruded about 7 inches from the face. None of these projectiles broke up, but plugged themselves into the softer nature of the plate, where they remained firmly fixed.

The armor-plate at the end of the experiment, though cracked in places, retained its position on the backing and was in a fair state of preservation. Though the shot discharged point-blank at the target penetrated the plate, none succeeded in getting through, but were arrested and held firmly in the grip of the metal.

If the above report is correct, the velocity and striking energy were somewhat less than with other plates tried. It is probable that they were exactly the same.

JESSOP PLATE—STEEL ON STEEL.

The report of this trial, another of the Portsmouth series, is reproduced from the Engineer of October 12, 1888. The dimensions of the plate are the same as those given for Cammell compound plate. Weight of powder charge, 48 pounds; projectile, 100 pounds; velocity, 1,976 foot-seconds; energy, 2,723 foot-tons. The peculiarity of the plate consisted in the front part being composed of twelve separate pieces of especially hard cast-steel, 3 inches thick, fastened to the rear portion in a special manner. The rear was formed of one solid piece of soft cast-steel 7.5 inches thick, holding the whole mass together. The theory of this design was that, should a shot strike one of the front hardened parts, the destruction would be confined to that particular part and prevent cracks extending all over the plate. The theory was fully supported in the test, but through an unforeseen defect in the method of holding the hard faces to the soft backing, the plate was not quite as successful as could be desired. Still, the results were far from discouraging, and the firm claim that they mark a new epoch in the manufacture of steel armor-plates. Holtzer 6-inch forged, hardened, and tempered armor-piercing projectiles and Palliser chilled shot were used in the test. This is the first and only armor-plate Messrs. Jessop have made; it was delivered as far back as December of last year, and the firm state that, had they known of the length of time that would elapse before the trial came off, they would have produced a much improved example of the new system.

VICKERS STEEL PLATE.

[Taken from advertisement of Vickers Sons & Co.]

The dimensions of the Vickers steel plate were the same as those above noted. The percentage of carbon in the steel was .34. The plate was secured to its backing by eight 4-inch bolts. The ballistic test was exactly the same as with the Cammell compound plate. The trial took place in September, 1888.

No. 1 shot, Holtzer, entered the plate and cut its way through, its point entering the backing. The projectile then rebounded in a direct line to the rear and was found 22 feet in front of target, quite uninjured. No cracks were developed, but there were eight radial fissures and a fringe 2 inches deep made about hole, which was 7 inches in diameter, 13.5 inches deep, and in exact form of the projectile. The back showed a circular bulge 12 inches in diameter and 3.5 inches in depth, was badly cracked through, and showed that the point had penetrated the plate.

No. 2 shot, Holtzer, entered plate to a depth of 13 inches, then rebounded, and after rolling about deck came to rest in front of plate, slightly distorted. The plate was not pierced; a bad crack was opened at upper part. The bulge at back was 12 inches in diameter, 1.8 inches deep, and slightly cracked.

No. 3, Palliser, entered plate and broke up, leaving point as far as shoulder in it. Diameter of the hole, 10 inches. Two slight radial cracks were started, one extended through the plate. Back bulge, 8 inches in diameter, 3 inches in depth.

No. 4, Palliser, broke up as did No. 3. No cracks were produced. Bulge, 10 inches in diameter, .85 inch in depth.

No. 5, Holtzer, pierced the plate, touched the wood backing, then rebounded, rolled about the deck for over a minute, finally coming to rest 24 feet to right of target, slightly distorted and set up. A moderate crack between holes 2 and 5 was made, and the other cracks were somewhat opened. Bulge, 12 inches in diameter, 2.5 inches deep and cracked through, leaving a hole, as in No. 1, but smaller.

At the conclusion the plate was practically intact for purposes of protection, although slightly cracked and pierced by two small holes, 3 and 1.5 inches in diameter. The backing was practically uninjured, though indented 3.5, 1.5, and 1.9 inches by shots 1, 2, and 5. But one bolt was sheared.

The striking features in the trial of the Vickers plate lies in the rebounding of the armor-piercing projectiles. Although these penetrated, and even pierced with their points the plate, yet they all rebounded several feet from the target, giving proof of its wonderful elasticity.

This steel plate, one of the first produced in England, certainly showed excellent qualities, and its behavior on trial has doubtless encouraged Messrs. Vickers Sons & Co. to persevere in their endeavor to produce heavy steel armor.

A second plate was tested in February, 1889. The dimensions of plate and the ballistic conditions were exactly the same as in former trial, which took place in September, 1888. The results were perhaps not quite so good as on first trial, the plate being more cracked, but the plate and backing were practically intact at end of the firing. Two of the Holtzer projectiles were broken upon striking.

BROWN STEEL PLATE.

The United Services Gazette, July 6, 1889, gives the following:

"The result of the test of Messrs. John Brown & Co.'s (Sheffield) steel plate, which took place recently on board the *Nettle* at Portsmouth, has been issued. The first shot (steel) was broken and thrown back on impact, and left a bulge about 6 inches high on the back of the plate. The second (steel) obtained about the same amount of penetration, but remained lodged, as did the fifth (steel), which got its point a little farther through. The third and fourth (chilled cast iron) produced so slight a bulge at the back as hardly to be perceptible, and broke in pieces. The lower half of the plate is without crack of any kind, but radiating from the point struck by one of the chilled shot near the right-hand top corner are four deep cracks which, however, did not sever the continuity of the plate. The deepest bruise in the wooden backing behind the plate was 8 or 9 inches deep, so that, had this plate been part of a ship's armor and had it received five shots (of which three were steel) from any enemy's 6-inch gun at 10 yards range, the effect upon the hull of the ship it protected would have been simply *nil*."

RECENT ARMOR ORDERS FOR ENGLISH SHIPS.

Messrs. Brown & Co. have received an order from the Admiralty for the side-armor (compound) for the *Repulse* and *Renown*; and Messrs. Cammell & Co. have a similar order for the *Hood* and *Royal Sovereign*. The weight of this armor is 1,264 tons for each ship, and the plates vary in thickness from 14 to 18 inches.

TRIAL OF GÖTAS ARMOR PLATE (LE CREUSOT).

The trial of steel plates for the Swedish armor-clad *Göta* took place at the Creusot Polygon on October 23, 1888.

The plate measured 6′.5 by 6′.5 by 9″.6, and weighed 5.65 tons. The gun was a 15^{cm}, 36 calibres long. Weight of projectile, 99.2 pounds; charge, 35.5 pounds prismatic brown powder; mean velocity, 1,839 foot-seconds. The energy due to this velocity is 2,324 foot-tons, or 125 foot-tons per inch of circumference, equivalent to a complete perforation of a wrought-iron plate 11.6 inches thick.

Three shots were directed against the angles of a centrally located equilateral triangle measuring 14.8 inches on the sides. The penetration of the first shot was 3.8 inches; of the second, 3.4 inches; of the third, 3.7 inches. The second shot caused a crack to radiate from the hole caused by the first round, and this was considerably enlarged by the third shot.

The photograph of the back of the plate taken after the firing showed the crack to have gone through, but the bolts all held and the plate was practically intact.

Last year's publication, pp. 384 and 385, gives some particulars of the tempering processes employed at le Creusot and Chatillon-Commentry; the former being based upon the utilization in the hardening process of the absorption of heat caused by the fusing or melting of a solid substance, and the latter using a lead bath. In June of last year two .32-inch steel plates, tempered as described, were placed in competition. Being fired at under exactly the same circumstances they behaved exactly alike.

C. E. VREELAND,
Lieutenant, U. S. Navy.

TORPEDOES.

The efficiency of the Whitehead or Schwartzkopff has been much increased recently. The latest models have blunt heads and long fine runs, which modifications secure the explosion of the charge nearer the hull of a vessel, and are said to increase the speed; the modification of the head also permits an increase of charge, the ratio of weight of explosive to total weight of torpedo now being as 1 to 5, whereas in the models produced from 1880 to 1885 the ratio was as 1 to 9 or 1 to 10; the side under water discharging apparatus has been improved to such an extent that good practice has been obtained from vessels at a speed of 14½ knots; and lastly, a device for opening the communication between the air flask and the motor engine after the torpedo reaches the water has been experimented with, and, according to report, successfully. The accuracy and reliability of the torpedo were demonstrated in the English naval manœuvres of 1888 (see pages 47 to 49) and in the exercises of the Spanish torpedo-boat flotilla (see page 447).

The contract made by the U. S. Navy Department with the Hotchkiss Ordnance Company for Howell torpedoes, requires the weight of explosive to be at least 17½ per cent. of the total weight of the torpedo, and the speed to be at least 22¼ knots. The torpedo in its perfected state has not yet been tried, and the discharging apparatus is still in the experimental stage.

The Brennan torpedo continues to be in favor for the projected defense of some points on the coast of England.

The Patrick torpedo has been tried in France and in the United States with a view to determining its applicability to the defense of harbors which can not be protected with submarine mines. Exhaustive experiments, carried out in the presence of a board of United States naval officers, have established the following facts: that the preparation of the torpedo requires considerable time but is not specially difficult; that the liquid acid kept in suitable vessels is safe and harmless in store and does not deteriorate to any serious extent with time; that the torpedo is adaptable to coast and harbor defense, and that it can be improved by some easily effected modifications. The speed now guarantied is 20 knots.

The Sims-Edison has also been materially improved during the past year.

AUTOMOBILE FISH TORPEDOES.

WHITEHEAD AND SCHWARTZKOPFF TORPEDOES.

The following table gives the dimensions, weight, and speed of the latest product of the factories of Whitehead & Co., and of the Berlin Machinery Construction Company* (formerly Schwartzkopff & Co.).

---

*In September, 1888, the Berlin Machinery Construction Company completed their two thousandth torpedo.

Nation.	Maker.	Cost.	Material.	Length.	Diameter.	Weight of charge.	Total weight of torpedo.	Speed.	
								For 400 metres.	For 800 metres.
				Feet.	*Inches.*	*Pounds.*	*Pounds.*	*Knots.*	*Knots.*
England				14.5	14				
France	Whitehead	$1,625	Steel	18.8	14.95		880	28.5	
Do	do	1,336	do	14.4	13.96		598	28	
Germany	Schwartzkopff		Phosphor bronze.	15.42	13.98	125	605	28.5	24
Italy	do		do	16.4	17.7	264	1,144	30	23
Do	do		do	15.4	13.9	125	605	28.5	24
Do	Whitehead		Steel	16.4	17.7	242			
Do	do		do	15.4	13.9	136			

England.—During the year ending December 31, 1888, two hundred and sixty-two 14-inch steel fish torpedoes have been manufactured and issued to the service. These torpedoes are of home manufacture, which has supplied them for a number of years past, an occasional purchase being made from Whitehead & Co., to acquire the improvements as made in their design.

The naval manœuvres of 1888 demonstrated conspicuously the value of this weapon under conditions closely approximating those of actual war. Four of the five ships lost by the blockading squadron were torpedoed, namely, the *Archer*, *Arethusa*, *Inconstant*, and *Tartar*, the torpedoes used being fitted with thin copper safety heads to preserve them and the targets from damage on contact. And here it is noteworthy as showing its immunity from accident in practicing personnel, that since 1875, the date of introduction into the English service, only ninety-nine Whiteheads have been lost, and in the Spanish torpedo-boat practice (see p. 448), only two of the thirty-two torpedoes with which seventy-five shots were made, received any serious damage.

For 1889–'90 the estimate for torpedoes, mines, torpedo and electrical stores, and gun-cotton for naval use is £110,000 ($535,700).

France.—The torpedo estimate for this year is $472,078.

Germany.—Le Progrès Militaire is the principal source of information regarding the following torpedo experiment which took place near Kiel during the naval manœuvres: The target was the *Drache*, a hulk of the old type of cruising gun-boat, of small class built in 1865, hull of wood. The torpedo discharge was to be made from the bow tube of a Schichau boat at full speed (about 19 knots), using the Schwartzkopff torpedo, at a range of 400 metres (437 yards). The torpedo-boats, fourteen in all, were manœuvred in squadron, under the command of Admiral Montz on the *Blitz;* when the boats arrived within 400 metres of the target one of them at signal from the *Blitz* discharged her torpedo while going at full speed. The *Drache* was struck amidships, the torpedo exploding and making a hole 2 metres long, which would have caused the hulk to sink had she not been buoyed with empty casks. The experiment possesses value only as showing the accuracy of the Schwartzkopff torpedo when discharged from the bow tube of a torpedo-boat at full speed.

Italy.—In 1885 the Government made a contract with the Berlin Machinery Construction Company for the delivery in ten years of seven hundred torpedoes, on condition that it should establish a torpedo factory at Venice. At the present time the buildings have been erected, and the installation of the greater part of the machinery has been completed, but the factory is not yet in full working condition.

It is reported that in the early part of 1889 the Government also made a contract with that company for two hundred torpedoes of the latest type, the larger size to have a speed of 30 knots for 400 metres, and the smaller, 28 knots for the same distance.

Russia.—Some of the torpedoes have been purchased from Whitehead & Co., and some from the Berlin Machinery Construction Company, but most are of domestic manufacture, one place of manufacture being the Russian Naval Gun Factory at Aboukoff. Up to the present about five hundred have been produced.

The torpedoes in use at present are, the Schwartzkopff bronze, the Russian steel, the Whitehead steel, the Russian bronze with steel flask, the Whitehead bronze. The diameter is uniformly 15 inches, but the length varies with the different patterns.

Spain.—The results of the practice of the Spanish torpedo-boats with the Schwartzkopff torpedoes are given on page 449.

HOWELL TORPEDO.

A contract was made January 3, 1889, by the U. S. Navy Department with the Hotchkiss Ordnance Company for thirty Howell torpedoes at $2,200 each, and ten launching carriages at $3,800 each, with the proviso that if the number of torpedoes should be increased to fifty or more before the acceptance of the first thirty, the price would be reduced to $1,936 each, and the price of each launching carriage would be reduced to $3,200 in case the total number should be increased to fifteen or more.

Ten of the torpedoes and all of the launching carriages are to be ready for delivery not later than July 1, 1890, and the remaining twenty torpedoes are to be ready for delivery not later than September 1, 1890.

In case the number of torpedoes and discharging apparatus is increased, the rate of delivery required is ten torpedoes and one discharging apparatus per month after September 1, 1890.

Specifications for the manufacture of the Howell automobile torpedoes and discharging apparatus:

"The greatest diameter shall not exceed 14.2 inches. They may have any uniform length between 9 feet 6 inches and 12 feet, and the total weight may vary, in an approximately proportional manner, from 428 pounds for a length of body or spindle of 9 feet 6 inches to 453 pounds for an extreme length of 12 feet, provided the space allowed for a charge of wet compressed gun-cotton shall be at least sufficient to properly stow a weight of that material equal to 17½ per cent. of the total weight of the loaded torpedo.

"The effective working range of the torpedo shall not be less than 400 yards, and the mean speed for that range shall be not less than 22½ knots per hour.

"The accuracy of the torpedo in the horizontal plane shall be such that in still water it will not be deflected more than 15 yards to the right or left of the point aimed at in a range of 400 yards. This to hold true if the torpedo be fired in any direction from a vessel at full speed (18 knots or less).

"The torpedoes shall be fitted with a means of maintaining themselves at a fixed depth while passing over the range, and their accuracy in the vertical plane shall be such that they will, throughout the working range of 400 yards, at all times maintain a submerged position within effective limits. When launched from a height of 4 feet from the water surface, after the first 95 yards' run, the deviation in the vertical plane from the depth for which the torpedo was set shall not exceed 2 feet. The initial dive shall not exceed 22 feet, measured from the surface of the water. When launched from a height of 11 feet above the water, the vertical deviation, after the first 100 yards' run, shall not exceed 2 feet, as before, and the initial dive shall not exceed 25 feet, measured from the surface of the water. The submerging apparatus shall be capable of ready adjustment, so as to cause the torpedo to maintain any desired depth, subject to the above condition.

"The torpedoes must be made of such material as will not deteriorate if given reasonable care and attention; however, if any small parts, such as springs, need special care they must be readily removable and readily put in place.

"The torpedoes must be stoutly made of good material, so as to be easily handled and manipulated, as would be necessary in actual naval service, and this without undue risk of injury.

"Until one of the torpedoes has successfully passed all the tests and has been accepted, no complete torpedo shall be tested except its fly-wheel has been submitted to the following test of its physical characteristics: It shall be spun for ten minutes consecutively at a speed of revolution at no time falling below the rate of 10,000 revolutions per minute, and at the end of that time it shall show no signs of deformation or other weakness.

"After one of the torpedoes has successfully passed all the tests and has been accepted, the materials of which it is made shall be examined under the inspection of the Department to determine their physical characteristics. Standards of materials will then be established by the Department for future manufacture, which standards will be incorporated in and become part of these specifications to govern the manufacture of all other torpedoes under the contract.

"The torpedoes must be safe in all respects from premature explosion while being loaded and handled.

"An efficient firing device must be provided, which must be safe while preparing and handling the torpedoes, and must not be liable to explosion from the effects of discharge. If the firing device is provided with a safety arrangement which requires manipulation, it must be of such a character as to readily show without close inspection when it is in the active and when in the inactive condition.

"The firing devices of the torpedoes must in all cases work effectively and certainly against targets sufficiently resistant to reasonably exhibit their effect. This to be demonstrated by exploding fuses operated by the apparatus in place and while the torpedo is in flight. As many experiments to determine this efficiency will be made as the Department may require.

"The firing apparatus must be effective whether striking normally or at an angle of 18 degrees with the plane of the target.

"The primer and firing device must be so arranged as to be readily and safely removed from its firing position and readily and safely replaced when desirable. Suitable packing arrangements for stowing the firing devices in a safe and suitable manner must be provided.

"The explosive charge must be so arranged and fitted that it can be readily and safely removed from the torpedo for stowage in a magazine.

"The mechanism of the torpedo shall work closely and smoothly, and the different parts shall be well secured in their relative positions by proper mechanical fittings and methods. This will be verified by shop inspection in each case, both while the torpedo is being manufactured and after its completion. Before accepting any torpedo its mechanism shall be examined after its final run, and it shall not be received if the machinery or any other parts show injury, distortion, or maladjustment.

"The torpedo must be so fitted that it will sink to the bottom at the end of its run. The primer must then be rendered innocuous automatically, and water must be admitted to the explosive charge within a reasonable time.

"The torpedo must be capable of being readily used for exercise and practice and recovered at the end of the run, and be made ready for another run speedily and without elaborate preparation. When used as above it must come to the surface at the end of the run. The mechanism must be so arranged that the torpedo will stop after running to any defined distance within its extreme range, *i. e.*, near enough to be a fair guide to its recovery.

"The torpedoes must be so assembled that the different sections may be separated so as to allow free access to all parts for the purpose of examination, adjustment, and repair.

"All such accessories of the torpedo itself as are directly necessary for its efficient service, either as an explosive weapon or for drill purposes, will be furnished by the contractor without extra charge.

"The launching apparatus must be efficient and simple in construction, readily manipulated, and capable of convenient train in the horizontal plane while the torpedo is in readiness for immediate discharge.

"It is to be well and strongly made, and not liable to injury from the ordinary vicissitudes of use on shipboard if given reasonable care and attention.

"It must be made of such material as will not deteriorate in service under the same conditions as to care and attention.

"It must be so made as to enable the Department, if it so desires, to protect the torpedo when in the loaded position from the effects of hostile fire by means of shields or otherwise, and this without altering the ordinary designs of a vessel of war.

"It must be capable of being readily and quickly prepared for action in every particular. It must receive the torpedo with facility and discharge it with certainty and safety.

"It must be capable of being used readily for the purpose of exercising with the torpedo.

"When installed for service, the greater part of the apparatus must be inside of the vessel in which embarked, and the torpedo must be entirely inside up to the final moment of discharge or detachment.

"The motor used for giving motion to the power-wheel of the torpedo must, when installed in the service manner, be capable of giving the required speed of rotation to the wheel within one minute of its application. Its application to and detachment from the torpedo-wheel, under these conditions, must be instantaneous and at will. The motor must be reasonably silent in its action.

"When connected to the torpedo under service conditions the motor must be at all times in readiness for immediate use, and when so connected it must be capable of running for at least one hour at the number of revolutions necessary for giving the torpedo its contract speed.

"The ejection of the torpedo must be at will and efficient to such a degree as not to deflect the torpedo in its flight, or to hang or jam in action, or to interfere with or be interfered with by the action of the power-wheel motor or the training of the carriage.

"The connections of the carriage with its emplacement and of the machines with the conduits for supplying motive power must be secure, of sufficient strength for the service required, simple, and compact, and must be so arranged as not to hamper the train of the carriage, the application of power to the torpedo, or the ejection.

"All such accessories of the launching apparatus itself as are necessary for applying the power, ejecting the torpedo, training the carriage, or for its efficient working, will be furnished by the contractor without extra charge.

"Of the torpedo-launching apparatus furnished by the contractor, one or more must be for use in the bow or stern of ships and the others for use on the broadside. The requirements of the specifications with regard to horizontal train will not necessarily apply to the type of apparatus intended for use in the bow or stern.

"No torpedo or launching apparatus will be accepted by the Department until standard drawings, in full detail, truly representing the article to be accepted, and approved as such, shall have been delivered to and accepted by the Department.

"No torpedo or launching apparatus will be accepted until one torpedo, together with its launching apparatus and all other appendages embraced in the contract connected with their practical use on board ship, have successfully passed all the test requirements.

"In addition to the tests of material and manufacture heretofore described or indicated, the following tests must be fulfilled:

"(*a*) The torpedo, fitted for exercise, must demonstrate its capability in still water of covering a range of 400 yards, at a mean speed of not less than 22½ knots per hour, without deviating more than 15 yards to the right or left of the point aimed at, or 2 feet above or below the depth for which it is set to run after it has passed the limit heretofore specified for recovering from its initial dive. This capability to be independent of the speed or motion of the vessel from which it is discharged or the horizontal direction of the range. And, furthermore, this capability must also be shown by actual trial to exist within the scope and meaning of the contract and specifications when the torpedo is used in a moderate seaway under such conditions as would obtain in a naval combat, as this is the chief use to which the torpedo will be put in service.

"(*b*) The torpedo, completely assembled, will have its fly-wheel spun for an hour at the number of revolutions per minute required to give the torpedo its contract speed, without showing signs of weakness or injury to any of its parts.

"(*c*) The torpedo, with its launching apparatus complete, must exhibit its capability of being readily and quickly prepared for action in every particular.

"(*d*) The motor and the ejecting apparatus must exhibit the power, strength, and efficiency demanded for fulfilling the projectile requirements of the torpedo, as hereinbefore specified.

"(*e*) The firing device must exhibit its security whilst the torpedo is being handled and discharged, its effectiveness of explosive power under the angular conditions of impact, heretofore specified, and its power of automatically rendering itself and the charge innocuous under the circumstances heretofore specified.

"(*f*) After use, and before final acceptance, the launching apparatus and motor must be in perfect order, and will be examined to ascertain whether they have sustained any injury in the trial.

"The Department may waive any or all tests if it so desires.

"All trials of the torpedo and launching apparatus will be made in such manner and by such persons as the Department may elect.

"The material of all articles embraced in this contract shall be of the best quality of their respective kinds, and the workmanship shall be first-class in every respect.

"No action of the Department, as described herein, shall be construed as in any way relieving the contractor from the responsibility of producing thoroughly efficient and satisfactory torpedoes, launching apparatus and articles pertaining thereto, within the meaning and limitations of the contract."

The workshop of the Hotchkiss Ordnance Company for the manufacture of the Howell torpedo has been located in Providence, R. I. It is equipped with tools of the latest type.

The principal improvements which have been made in the torpedo are chiefly mechanical. The fly-wheel is now mounted in a compact and rigid frame of phosphor-bronze, and turns upon friction rollers. The driving gears upon the wheel are still of steel, but the gears upon the propeller shafts are of vulcanized fibre.

The form is the same as that before used, but the body of the torpedo, of spun brass, is much improved in workmanship. It is made in four sections, joined together by locking frames with bayonet joints.

Motion is now communicated to the fly-wheel by means of a clutch coupling driven by a Parsons steam turbine motor.

The following are the dimensions:

Length of body of torpedo	feet	9
Length over all, including propeller	do	9.5
Greatest diameter	inches	14.2
Displacement	pounds	410
Weight of explosive charge, at least	do	72
Least speed allowed by contract	knots	22.5

CONTROLLABLE TORPEDOES.

BRENNAN TORPEDO.

The English War Department proposes to expend £12,000 on this torpedo during the year ending March 31, 1890. Five or six of these torpedoes have been completed and from thirty to forty are being constructed at Chatham for distribution at different points along the coast, the first point to be equipped with this weapon being the Isle of Wight, for the protection of Portsmouth Harbor.

A testing station has been established at Garrison Point, Fort Sheerness, where a long series of experiments is shortly to be carried out.

PATRICK TORPEDO.

Description and dimensions of this torpedo have already appeared in No. VI, page 35, and No. VII, page 393. A torpedo purchased by the French Government was shipped from New York in August of 1888. Its dimensions (partly given in No. VII) are as follows: Length of torpedo proper, 40 feet; greatest diameter, 24 inches; length of float, 45 feet; greatest diameter of float, 18 inches; weight of torpedo proper, 6,543 pounds; displacement, 5,163 pounds; weight of float, 890 pounds; displacement, 3,676 pounds; total weight of weapon, 7,433 pounds; magazine charge (dynamite), 200 pounds; length of cable multiple (two-wire), 8,000 feet; length of cable single, 14,200 feet; speed for one statute mile, 17 knots; propeller single, two-bladed, diameter 31 inches, pitch 42 inches; controlling battery, bichromate, 100 cells.

It has been applied experimentally to the defense of Le Goulet (the Narrows) of Brest for the purpose of determining its value for that use, defense with submarine mines being considered impracticable. The Goulet is a strait from 1,000 to 2,100 yards wide; its bottom is full of jagged rocks, and differences in depth of 20 to 40 fathoms occur within a few feet (horizontally) of each; the current runs at the rate of 4 to 5 knots, with many whirlpools and cross and counter currents, which would necessitate the passage at full speed of a hostile ship.

At New York on July 30, 1888, the torpedo made a speed of 19.2 knots for 5,250 feet, and on another trial, August 2, 1888, 21.3 knots was made over the same distance.

At Brest in January, 1889, the following experiment was made: The torpedo was started from a float and was directed against a target 196 feet long, which was towed past at a distance of 800 yards and with a speed of 15 knots. A considerable sea was running and it was estimated that the torpedo would have struck if the after part of the target had not been washed away.

A series of experiments were carried out last summer at College Point, N. Y., before a Board of United States Naval Officers for the purpose of determining the value of the torpedo for coast defense. The torpedo used was the first made by Mr. Patrick. Its dimensions were: Length of torpedo proper, 36 feet; greatest diameter, 22 inches; length of float, 42 feet; greatest diameter of float, 13 inches; weight of torpedo proper, 4,700 pounds; displacement, 4,334 pounds; weight of float, 900 pounds; displacement, 2,627 pounds; total weight of weapon, 5,500 pounds; magazine charge (dynamite), 200 pounds; length of cable multiple (two-wire), 7,000 feet; length of cable single, 13,200 feet; speed for one statute mile, 16 knots; propeller single, two-bladed, diameter 27 inches, pitch 36 inches; battery, bichromate, 100 cells.

The experiments extended from June 24 till November 5, 1888. Seven trials were made and the qualities of the torpedo tested. It was found that with slight modifications both the speed and the manœuvring power could be increased, the former by decreasing the weight, which was unnecessarily great, owing to the excessive weight of the acid flask, and the latter by substituting a double screw for the single screw, whose action caused the float to heel over and affect the steering. The tendency of other torpedoes, the Ericsson and the Whitehead, to turn out of trim under the action of a single screw has long since been obviated by the use of two concentric screws with opposite pitch and opposite rotation, so that the application of this device would not be experimental.

The finding and recommendation of the board were as follows:

Finding: The Board is of the opinion that the Patrick torpedo in its present condition is adapted to naval warfare in connection with the defense of the harbor and coast, and that the torpedo can readily be improved so as to make it better adapted for this purpose. * * *.

Recommendation: The Board recommends (1) that one or more torpedoes of this pattern be purchased for a course of extensive experiments at the Torpedo Station in order to obtain valuable data as to the utility of this class of torpedo and as to the manner of improving this pattern in particular. * * *

An order was given Mr. J. N. H. Patrick, February 26, 1889, under conditions, of which the following are the most important:

The capacity of the explosive chamber is to be sufficient for the stowage of 400 pounds of dynamite. The explosive must be so arranged and fitted that it can be readily and safely removed from the torpedo.

The centre of the explosive charge to be at least 3 feet below the surface of the water when exploded.

Speed to be 20 knots for 5,280 feet.

Manœuvring and firing under the conditions of service to be readily, certainly, and completely accomplished by the manipulator of the operating apparatus.

If a torpedo fulfill the above and other conditions, it will be purchased for $20,000, and an order, contingent upon the acceptance of the first, will be given for two more, the price of which will be $17,500 each.

The first torpedo is to be complete and ready for trial within five months, and the other two within two months after the acceptance of the first, and a penalty of $50 and $75 to be paid for delay beyond the first and second months, respectively, and $100 for each month thereafter.

If the speed of the first torpedo is less than 20 knots, but more than 15, and meets the other requirements, it will be accepted at a reduction of $250 for each quarter knot less than 20 knots on the original price, $20,000. If the speed is less than 15 knots, the torpedo will be rejected, and in both cases the order for the other two withdrawn.

SIMS-EDISON TORPEDO.

The Sims-Edison Electric Torpedo Company claim for their weapon a material increase of speed. This has been effected by an improvement in the lines of the torpedo and float, and by the employment of an American cable which has been found to possess a much better insulation than the English cable formerly used.

The manœuvring power, too, is said to have been much increased by a modification in the manner of connecting the float with the torpedo.

A speed of 25 miles [21¾ knots] is *expected* when a new motor and propeller have been substituted, which will more completely utilize the increase of power now transmitted to the torpedo.

The principle of the working of the torpedo remains unchanged. It is described in No. VI, pp. 41, 42.

OTHER TYPES.

A Russian gun torpedo.—A gun torpedo is issued to the Russian naval service for use from launches in place of the spar torpedo. It is of fusiform shape, and is provided with vertical set fins and a set horizontal rudder. Length, 7 to 9 feet; diameter, 15 or 16 inches. The material is steel. The torpedo is ejected from a tube by gunpowder impulse some 200 or 300 feet. After reaching the water it travels at a depth of about 12 feet, for which the horizontal rudders or fins are set. The explosive is gun-cotton.

Pietruski torpedo.—The Pietruski torpedo is the invention of Lieutenant Pietruski von Siemnozowa of the Austrian Navy. The drifting type is intended to be thrown overboard from a vessel under way or from boats. Usually several torpedoes are connected together by lines. When first put in the water they are harmless, but the action of the sea water soon vitalizes the chemical fuse, which will then explode on contact. The torpedo is maintained at a fixed depth by a small float, which would generally escape detection. The fuse is put out of action and the torpedo raised by means of a small line attached to the float.

NETS.

The following is the conclusion reached by the Committee on the English Naval Manœuvres of 1888 as regards the value of torpedo nets: * * * "Certainly as at present fitted they can not be carried by vessels under way without impairing their efficiency and compromising their safety."

The Army and Navy Journal of March 16, 1889, is the authority for the following: "Every (German) armor-clad cruiser or armored gunboat is fitted with torpedo defense nets, and the booms are kept permanently shipped, with rigging on, the nets bent and neatly stowed in shallow iron trays or boxes running round the ship. On account of ground tackle the bow defense is kept separate. By this means the evolutionary squadron last summer had their nets out at sea in three minutes from the hauling down of the signal. Wooden booms are preferred to steel or iron."

J. T. Newton,
Lieutenant, U. S. Navy.

TORPEDO-BOATS.

SURFACE TORPEDO-BOATS.

The ability of torpedo-boats to harass and inflict severe losses on a blockading squadron was strikingly shown during the English naval manœuvres of 1888 (see pages 40 *et seq*). Of the five ships lost by the blockading squadrons, four, the *Archer*, *Inconstant*, *Tartar*, and *Arethusa*, were torpedoed by torpedo-boats. The following summary represents the state of development reached by the principal naval powers as regards dimensions, speed, and armament.

Dimensions.—This year the British Admiralty is reported to have adopted a sea-going type 135 feet long. In 1888 the boats built for sea-going purposes were 130 feet long of the No. 79 Yarrow type. The No. 50 Yarrow type of second-class boat 60 feet long continues in favor, but wooden vedette boats 53 feet long were advocated by the Committee on Naval Manœuvres, and two have been ordered to be built for trial, with a view to their adoption, if successful, in place of the No. 50 type.

In France the failure of the 35-metre type has had much to do with setting torpedo-boat construction back to the experimental stage, in the hope of inventing class-types containing qualities which have so far eluded successful combination. Of the *éclaireur-torpilleur* class three types are building: the *Avant-Garde*, 137 feet long with a displacement of 120 tons; the *Alarme, Aventurier, Défi*, and *Téméraire*, of the *Ouragan* type, 151 feet long with a displacement of 147 tons; the *Agile* and *Audacieux*, 139 feet long with a displacement of 103 tons. Of the first class, four 78-ton boats and fourteen 52-ton boats are building.

In Germany the division boats and 121-foot Schichau boats continue to give satisfaction.

The Italians have made an innovation in their flotilla by the addition of five sea-going Schichau boats, 152 feet long with a displacement of 130 tons. Since 1886 all their first class have been of the 127-foot Schichau type.

Speed.—In England, for the 130-foot boats the speed required is 22½ knots, and for the 60-foot boats, 17½ knots. These are probably measured-mile speeds.

In France, the *éclaireurs-torpilleurs* are to have a speed of 20½ knots. The 111-foot type must during a six-hour run develop a mean speed of 18 knots without forcing the engine, and during one hour of the run make 20 knots.

In Italy a speed of 19½ knots is required from the 127-foot boats during a three-hour run in calm weather in a smooth sea.

From the above it will be noticed that endurance is preferred to excessive measured-mile speed. The uncertain performance of boats built to attain the highest measured-mile speed is strikingly shown by the result of the Spanish torpedo-boat speed-trial (see page 451), and by the reported defects of the Italian *Avvoltoio* class (see page 446).

Armament.—The English 130-foot boats carry 3-pounder R. F. guns. They have one built-instem tube and two turn-table tubes abaft. Second-class boats carry a machine-gun and two torpedo-dischargers aft. The torpedo tubes of both classes are fitted for gun-powder impulse.

The French boats of Normand design—the *Avant-Garde* and the 34-metre boats—carry a spar torpedo forward and one or two turn-table tubes aft. The *éclaireurs-torpilleurs* of the *Ouragan* type built by Chantiers de la Loire have four tubes (see page 189), and those built by the Méditerranée, three spoon tubes. All tubes are fitted for gunpowder ejection. The artillery consists of R. F. guns for all the types.

The German 121-foot boats have two fixed bow tubes, air impulse, and two 37mm. Hotchkiss R. C.

The Italian 152-foot boats carry two 37 mm. Hotchkiss R. F., two 57 mm. Hotchkiss R. F., one 37 mm. Hotchkiss R. C., one fixed bow tube-air impulse, and two turn-table tubes aft, gunpowder impulse. The 127-foot type carry two 37 mm. Hotchkiss R. C., one built-in stem tube, air impulse, and one turn-table tube aft, gunpowder impulse.

In brief, the French have abandoned the built-in bow tubes. Their tubes or guns are mounted on deck, and the space formerly taken up below by the discharging apparatus is now available for other purposes. The English and Italians retain one built-in tube, and only the Germans, of the leading nations, still cling to the double built-in bow tubes.

England and France have adopted the steel Whitehead, and their boats are equipped with tubes fitted for gunpowder impulse. Italy has adopted the Whitehead and the Schwartzkopff, and her torpedo-boats are fitted with both systems of discharge. Germany uses only the Schwartzkopff, and her torpedo-boats are in almost all cases fitted with tubes for air impulse.

The rapid-fire gun has almost universally supplanted the revolving cannon on seagoing and first-class torpedo-boats. The remarkable inaccuracy of revolving cannons and machine-guns when used on torpedo-boats is shown by the result of the target practice held by the Spanish flotilla (see pages 449 to 451).

SUBMARINE BOATS.

The *Gymnote*, 59 feet long, and the *Peral*, 72 feet long, were both laid down in October, 1887. Their construction represents a reaction in favor of the diving type after the unsatisfactory trials with the pull-down or Nordenfelt type.

Their shape and the application of the principle of the hydrostatic piston to regulating the immersion have been copied from the Whitehead torpedo.

The motive power is electricity supplied by storage batteries which possess the advantage of being invariable in weight. On the other hand the life of this source of power is quickly exhausted and its application is limited to the smaller class of submarine boats which, however, may be used as tenders to ships or for the defense of ports.

Neither the *Gymnote* nor the *Peral* has proved a satisfactory solution of the problem of submarine navigation, but they have indicated the direction in which better results may be expected than have yet been obtained.

For counter-mining, the French are testing the merits of the *Goubet*, an 18-foot submarine boat, and they have ordered another, somewhat smaller boat, for the same purpose, from the Compagnie Générale des Bâteaux Parisiens.

AUSTRIA.

Schichau delivered lately the *Krähe*, *Staar*, *Kukuk*, and No. XXXIV. The three first are of 83 tons displacement, and developed on trial at Elbing a maximum speed of 22.6 knots.

Four more 83-ton boats are finishing at the Schichau works.

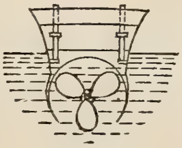
Six 83-ton boats of the Schichau type, the *Flamingo*, *Gaulkur*, *Harpie*, *Marabu*, *Weihe*, and *Secretär*, are building at the works of the Stabilimento Tecnico, Trieste. Their torpedo armament is to consist of one stem tube fitted with air discharge, and one turn-table tube aft fitted for gunpowder discharge.

Four second-class 56-ton boats are building at Pola. Their maximum speed is to be 20.5 knots.

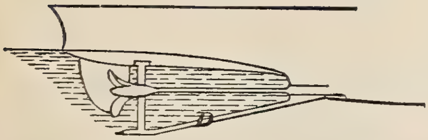
DENMARK.

The *Narhvalen* and *Havbestan*, built by Thornycroft, were delivered in the Autumn of 1888. The dimensions are: length, 137 feet 10 inches; beam, 14 feet; draught of water, 7 feet. The machinery consists of a set of triple-expansion engines, supplied with steam at 200 pounds per square inch, by two patent tubulous boilers. There are two bow tubes, with their muzzles well inboard so as to avoid any projection, which by throwing up spray might betray the boat's position under the electric light at night. Aft, there is a double tube revolving on a turret. The barrels of this double tube are parallel to each other, with their muzzles at opposite ends. The artillery consists of two 5-barrel 37 mm. Hotchkiss R. C., one mounted on the conning tower forward, and the other on the deck aft. The speed test required by contract was a 3-hour run at 22½ knots with 10 tons on board, and at 21½ knots with 20 tons on board. On trial 22.66 and 21.53 knots were made under the above conditions, respectively. With the 20-ton load the displacement was 100 tons, I. H. P. 1,270. The turning circles were made on an average in 80 seconds to port, and 80 seconds to starboard. The after end of the propeller shaft (see cut) is supported by a strong vertical post, the lower end of which connects with a bar, D, which, with the side rudders protects the propeller from being fouled as shown in sections A and B.

A



B



During the Danish manœuvres of 1888 one of the boats, with a similarly protected screw, was driven 14 times at various angles over a 2½-inch steel hawser, fitted with cork floats which gave it a surplus buoyancy of 8 pounds per fathom. This boat was not caught at any time, but the propellers of other boats, not so protected, were easily fouled.

With regard to the boilers of this type Captain Nielson, Director of Naval Construction, in a communication dated January, 1889, states that all the torpedo-boats supplied by Thornycroft to the Danish Government during the past two years are fitted with the patent tubulous boilers. The *Narhvalen*, *Havbestan*, *Storen*, and *Soloven* are each fitted with two of them, and four second-class and four patrol-boats with one. After enumerating the many advantages this type possesses over the locomotive boiler, he concludes as follows:

"Our engineers are in fact so satisfied of their superiority over the locomotive boiler that we, without hesitation, fit these boilers in all new boats, and when locomotive boilers in the older boats have to be taken out we replace them with the tubulous boiler."

ENGLAND.

Six first-class boats have been ordered from Yarrow during the year ending March 31, 1889, and their construction is considerably advanced. Length, 130 feet; beam, 13 feet 6 inches. Triple expansion engine of 1,100 I. H. P.; locomotive boiler, with a grate surface of 30 square feet; radius of action, 2,000 miles; speed, 22½ knots. The armament is to consist of three-pounder R. F. guns and three torpedo tubes, one built-in stem tube and two training tubes abaft.

These boats belong to what is known as the No. 79 type, of which the following are some of the interesting features: The condenser is supplied with refrigerating water automatically by the passage of the boat through the water. The shell of the boiler is of mild steel, and the tubes are of brass. For the purpose of maintaining a depth of water over the fire-box, while pitching, the crown is made with a drop of

5 inches commencing 12 inches from the tube sheet. The fire-box is inclosed in a complete water-tight casing, so arranged that the air for combustion has to pass over the top of this casing and then down into the furnace. The object of this device is to prevent the extinction of the fires in case the compartment is flooded. Experience has shown that with the boiler completely immersed the boat is still capable of steaming 40 to 50 miles. The rudder is made in one piece; its lower part extends forward of the stern-post, and is consequently partly balanced. It is hung on the stern-post, whose length is equal to the depth of the stern, which is much cut away at this point. The dead-wood aft is removed. The shaft comes through the bottom and is supported by a two-arm bracket close to the propeller, which is forward of the rudder. The manœuvring power resulting from this arrangement is excellent.

It is stated in Engineering of April 5, 1889, that a new type of torpedo-boat has been adopted by the Admiralty of the following dimensions: Length, 135 feet; beam, 14 feet. There will be a turtle-back forward, and the tubes will be fitted for gunpowder impulse. The boats laid down during the coming year will be of this pattern.

Ten second-class boats of the No. 50 type have also been ordered from Yarrow. Length, 60 feet; speed, 16 knots; displacement, 11 or 12 tons. The armament is to consist of a machine gun and two torpedo dischargers aft. The description of this type appears in No. VII, p. 400.

The report of the Committee on Naval Manœuvres advocates the adoption of a new type of wooden vedette boats on the ground of their being better sea boats, less liable to damage, and more easily repaired than the steel second-class boats now carried by sea-going battle-ships. This recommendation of the Committee gives likelihood to the statement that in February, 1889, an order was given to Messrs. White & Sons, of Cowes, to lay down two sample vedette boats of wood, 53 feet long, speed required, 15½ knots, and that this order will be followed by a much larger one in the event of their success.

A new type of boat has been designed, adapted alike for mining or coaling, and intended to be carried on board large ships. The first example of this type is now undergoing trial, and, if successful, it is proposed to add a number during the coming year.

Messrs. William Doxford & Sons have lately built a liquid-fuel torpedo-boat of the following dimensions: Length, 137 feet; beam, 13 feet 9 inches; single screw; triple expansion engines, with cylinders 15, 22½, and 33½ inches diameter; stroke, 18 inches. The boiler is of the locomotive type, with a wet-bottom fire-box. The furnace is open at the front to allow for the numerous jets, thirty-one in all, by which the fuel is injected into the furnace under an air pressure of 40 pounds per square inch. Only one man is required to look after the fire, and when the burners are lit he has little or nothing to do. Fourteen tons of fuel, a kind of petroleum or tar refuse, are carried in the double bottom, which allows other use to be made of the space usually allotted for the bunkers. At the beginning of March of this year five runs were made over the measured mile, and their average gave a speed of 18.9 knots; steam pressure, 160 pounds; vacuum, 23 inches; revolutions, 312. The whole question of fuel resolves itself into one of cost. The oil consumed was purchased at 2½ *d.* per gallon; coal is purchased, according to the terms of the Admiralty contract, at 14 *s.* per ton. A pound of coal will evaporate 10 pounds of water; a pound of oil will evaporate 15 pounds of water. With oil fuel, however, there is no dust, little or no smoke, trimming is dispensed with, potential energy weight for weight is one-half greater, and the supply of steam, being independent of the firing, is more regular.

ENGLAND COLONIAL.

The Admiralty have advised and assisted the India Office in the construction of seven first-class torpedo-boats, which were practically complete in February, 1889, and about to be dispatched to India. Three of these boats, distinguished as Nos. 1, 2, and 3, built by Thornycroft, are of the following dimensions: Length, 134 feet 7 inches; beam, 14 feet 9 inches; displacement, 96 tons. There are two triple expansion engines, developing 1,270 I. H. P., and supplied with steam by two Thornycroft tubulous boilers. The rudder and the protection of the screw is shown in cuts, page 439. The armament consists of a built-in stem tube and a double tube pivoting around each of the two conning towers, all fitted for gunpowder impulse, and Nordenfelt guns mounted on the conning towers. On October 12, 1888, No. 2 made over the measured mile 23.156 knots, the mean of six runs. The speed guarantied was 22 knots. Circles to port and starboard going ahead were made in one minute twenty-six seconds and one minute twenty-three seconds, respectively; the same, going astern, were made in one minute forty-three seconds and one minute twenty-nine seconds.

Three others of the seven mentioned above were built by Mr. J. S. White, of East Cowes.

The seventh was built at Paisley, England, by the firm of Hanna, Donald & Wilson.

FRANCE.

THE 35-METRE TYPE.

Casualties have happened to two of the 35-metre boats under conditions which prove the type to be unseaworthy.

Six of this type had been ordered from the Société Anonyme des Anciens Établissements, Cail, one No. 92 had been accepted; six from the Chantiers de la Gironde; twelve from the Ateliers de la Loire; sixteen from the Forges et Chantiers de la Méditerrannée, eight Nos. 99, 100, 101, 102, 103, 104, 110, 111 had been accepted; eleven from Schneider et Cie.

Further work on those building has been suspended, and those which had been accepted have been placed in reserve, by order of the Minister of Marine, until such modifications of the plans can be carried out as will render the type seaworthy.

One of the casualties referred to was the capsizing of No. 102, a 35-metre boat built by the Forges et Chantiers de la Méditerrannée. The accident happened on March 1 abreast the Ile des Embiez in the Baie of St. Nazaire, when the torpedo-boat flotilla were returning to Toulon after their manœuvres. The weather was moderate; there was a strong wind from the northwest and swell from the southwest. The boats were in single column steaming to the southward. Nos. 36 and 52, 27-metre boats of 27 tons displacement, and No. 101, a 35-metre boat of 56 tons displacement, had preceded No. 102. On reaching a point 800 metres to the northward of the Ile des Embbiez and 300 metres to the westward of Casserlane Shoal, No 102 was suddenly thrown on her beam ends and immediately turned turtle, her screw continuing to revolve in the air. There was no apparent cause for the disaster. The sea was so moderate that berthons (collapsible boats) and dinghies were at once launched, without mishap, from the sea-going torpedo-boat *Capitaine Mehl* to rescue the survivors and to make fast a line to the capsized craft, floating bottom up, for the purpose of towing her into shallow water. Six men were lost—three were drowned, and three inclosed in the fire-room were suffocated.

Twenty days later, March 21, four torpedo-boats, Nos. 110 and 111, 35-metre boats No. 71, a 33-metre boat, and No. 55, a 27-metre boat, left Havre at 11.30 a. m. for Cherbourg. The barometer was very low; the storm signal was flying, but at Havre the weather was calm. In the Baie de Seine the wind came out from northwest and veered to north. As the flotilla approached Barfleur Point the wind freshened in squalls and the sea became rough. When 7 or 8 miles east of Barfleur Point the boats were struck by a heavy squall. For some minutes they lost sight of each other, each navigating for safety. On clearing, No. 110 had disappeared. It is supposed that she foundered during the squall, from the fact that just after it, No. 111 reported having seen water breaking as over a wreck awash, but the sea being too rough to permit any attempt at life-saving further investigation was abandoned. No. 55, finding she could not reach her destination, returned to Havre. Nos. 71 and 111 reached Cherbourg that afternoon, after a very rough trip. No. 71 sustained no damage. The plating of No. 111 was stove in and her hull was wrinkled. She was leaking so rapidly that it was necessary to keep the pumps going until she was hoisted to keep her afloat.

A brief history of the development of the 35-metre type will best show the origin of the defects that were incorporated in its plans.

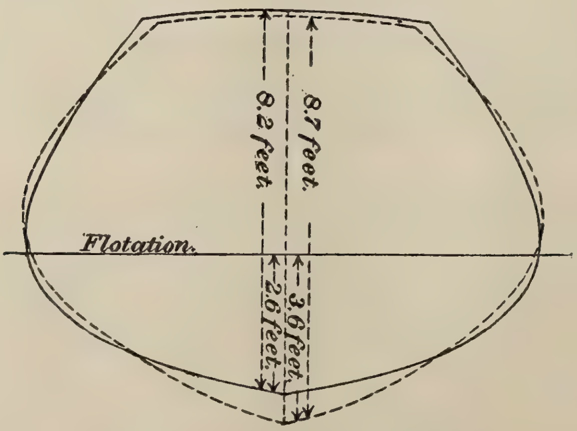
In May, 1885, Admiral Galiber, Minister of Marine, made contracts with the Société Anonyme des Anciens Établissements, Cail, the Chantiers de la Gironde, the Ateliers de la Loire, the Forges et Chantiers de la Méditerrannée, and Schneider et Cie (Le Creusot) for the construction of thirty torpedo-boats of the 60-to-74 Normand type, the dimensions of which had been modified as follows: Length, 111.5 feet (34^{m}); extreme outside breadth, 10.6 feet; depth between deck and keel, 8.2 feet; draught of water aft, 6.5 feet; displacement, 50.9 tons; speed, 20 knots. The contract price was 160,000 francs. A. Normand, the designer, would not accept the terms.

Two months later an order was issued to suspend work. The Conseil des Travaux, acting on the advice received from the maritime prefectures, decided to have the launching-tubes raised and to have the plans altered accordingly. Plans of the following dimensions, as modified by the Société de la Méditerrannée, were adopted: Length, 114.8 feet (35^{m}); extreme outside breadth, 10.6 feet; depth between deck and keel, 8.2 feet; draught under screw, 6.5 feet; displacement at this draught, 53.75 tons; immersed surface of the midship section, 23 square feet; estimated speed, 20 knots: I. H. P., 525.

When Admiral Aube became Minister, he concluded the contracts for the 35-metre type, and increased the number to fifty-one.

Hardly any of the original plans of A. Normand had been retained. The forward part had been built up almost vertically from the stem to the conning tower, thereby exposing considerable surface to the action of the waves. The after body made a much larger angle with the axis of the screw, a modification which diminished its propulsive effect.

The water-line of the 60-to-74 modified type fell 10 or 11 inches below the greatest breadth of the midship section, while in the 35-metre plans the water-line fell at the greatest breadth, a modification which causes the stability to diminish with increased immersion. With the 33-metre boats, the tumble-home sides are an advantage, but with the 35-metre type they become a defect. The 33-metre boat, No. 71, with tumble-home sides, sustained no injury from the same weather in which No. 110 foundered and No. 111 was seriously damaged. The accompanying sketch shows the midship sections of the 35 and the 33-metre boats represented by the full and by the dotted lines respectively.



Fifty-three tons was the estimated displacement of the 35-metre boats, but as the speed called for could not be made, an attempt was made to supply the deficiency by putting in larger boilers. This increased the displacement to 56 tons, diminished the flotation, and raised the centre of gravity, both of which changes still further diminished the stability.

It is reported that the Minister of Marine and the Compagnie des Forges et Chantiers de la Méditerrannée have agreed on the following modifications to be applied to the 35-metre boats: Their sides are to be built up vertically with thin plating, and the space between this plating and the tumble-home sides is to be filled in with cellulose; the raised upper works forward are to be lowered; a single tube will be left in the bow, and two will be placed aft close to the side; the artillery will consist of two 37^{mm} R. F. guns.

THE 34-METRE NORMAND TYPE.

Fourteen single screw 34-metre boats to be completed in the early part of 1890, are building by Normand and by the Sociétés La Loire, Le Creusot, and La Gironde. They are designed by A. Normand, and are to have the following dimensions: Length, 111.5 feet (34^{m}); beam, 11.48 feet; depth from deck to keel amidships, 6.5 feet; draught aft under propeller, 7 feet; displacement, 52.8 tons; maximum speed loaded, 20 knots. The engine is triple expansion and the boiler is tubulous, of the Du Temple design. They are manœuvred by two rudders, one forward and one aft. The armament is to consist of two spoon tubes for launching 19 foot (5.75^{m}) torpedoes, mounted aft on the same central pivot platform and protected by a steel shield; one spar torpedo forward; two 37^{mm} R. F. guns (light model). The boats are lighted by electricity and provided with a projector. During a six-hour run the mean speed required is 18 knots without forcing the engine, and during one hour of this run, a speed of 20 knots. The equipment is to be complete and coal carried sufficient for a forty-hour run at 12 knots.

BUILDING AND LATELY BUILT.

Ateliers de la Loire.—The *Bouet-Villaumez* and *Edmond Fontaine*, 134-foot boats of 67 tons, are building at the Claparède works, St. Denis, and were to have been completed by January 1, 1889. Cost each, of hull and machinery, $57,900; of artillery, $3,088.

The *Ouragan* failed to fulfill the speed requirements of the contract, and she was returned to the Ateliers de la Loire in August, 1888. Her plans have probably been modified in the hope of finally attaining the speed required. It is stated that the Minister of Marine offered to accept the boat at a reduction of $38,600 and that his terms were rejected.

The *Alarme*, *Adventurier*, *Défi*, *Têmêraire* have been built. These boats are of the *Ouragan* type and have the same dimensions. Their armament consists of four launching tubes, similar to those of the *Ouragan* (see page 189), and two 47^{mm} R. F. guns. The speed required is 20½ knots.

Nos. 136, 137, 138, 34-metre boats, are building. The contract was signed February 13th, 1889, and they are to be within 15 per cent. of completion by January 1, 1890. Price of each, including artillery, $45,160.

Chantiers de la Gironde.—Nos. 142, 143, 144, 34-metre boats are building, under the same conditions as those building by the Ateliers de la Loire.

Forges et Chantiers de la Méditerrannée.—The *éclaireurs-torpilleurs Audacieux* and *Agile* have been built. The contract was signed on July 25, 1888, and the *Audacieux* was launched May 1, 1889. Their dimensions are: Length, 139 feet; displacement in tons, 103; horse-power, 1,100; speed (estimated), 21 knots; contract speed, 20½ knots; cost each, of hull and machinery, $84,920; of artillery, $3,088.

Augustin Normand et Cie.—The *Avant-Garde*, building, is of the following dimensions: Length between perpendiculars, 137 feet 9 inches; beam, 14 feet 8 inches; depth between keel and deck, 9 feet 2 inches; displacement, loaded with coal for a voyage of 1,800 miles at 10 knots and complete armament, 119 tons; speed at this displacement, 20½ knots.

The armament is to consist of two turn-table tubes for 19-foot torpedoes, one placed over the boiler, the other abaft, a spar torpedo, and two 47^{mm} H. R. F. The boat has twin screws arranged as described on page 229. The contract was signed November 7, 1887. Cost of hull and machinery, $93,990; of artillery $3,088.

A contract was made September 12, 1887, for four 78-ton boats, Nos. 126, 127, 128, 129. Nos. 126 and 127 were launched in November, 1888. Cost each, of hull and machinery, $62,610; of artillery, $3,860. Nos. 128 and 129 were to have been within 5 per cent. of completion by January 1, 1889. Cost, each, of hull and machinery, $61,760; of artillery, $3,860.

Nos. 130, 131, 132, 133, 134, 135, 34-metre boats, are building. The contract was signed January 23, 1889, and the boats are to be delivered by January 1, 1890. Price of each including artillery, $52,238.

Schneider et Cie (*Le Creusot*).—Nos. 139, 140, 141, 34-metre boats, are building under the same conditions as those building by the Ateliers de la Loire.

J. J. Thornycroft & Co.—The *Coureur*, described in No. VII, page 401, was tried at Cherbourg and made 23.5 knots over the measured mile and 23.6 knots on the two hours' run. During another trial at sea she made 17½ knots under one boiler. The terms of the contract with respect to coal consumption were 8.36 tons per 1,000 knots at a speed of 10 knots, and the consumption established at Toulon by a six-hour trial was 7½ tons. During a trip from Cherbourg to Toulon, a distance of 1,968 knots, the following was the rate of consumption, which, owing to the better quality of coal, was less in the first two stages of the voyage than in the last: From Cherbourg to Brest, 205 knots, 19.82 tons per 1,000 knots, using briquettes; from Brest to Cadiz, 943 knots, 18.45 tons per 1,000 knots, using briquettes; from Cadiz to Toulon, 820 knots, 22.7 tons per 1,000 miles, using Welsh coal. In a testimonial dated January 22, 1889, the Minister of Marine stated to Mr. Thornycroft that the *Coureur* gave entire satisfaction as to seaworthiness during the above-mentioned trip. Her boilers likewise gave very satisfactory results, although the utilization of the fuel was not so complete as during the trials.

GERMANY.

A contract for sixteen sea-going torpedo-boats was awarded to Schichau in September or August of 1888. They are to have 1,500 I. H. P., and a speed of 23 knots. In April, 1889, the construction of several of these boats was so far advanced that a few days' work would place them in condition for launching.

The Deutsche Heeres Zeitung of June 5, 1889, is the authority for the statement that two more division boats have been ordered from Schichau. The sixth is now finishing by that firm which has built all of this class. Nos. 7 and 8 are to have greater speed, so that they may be used as torpedo-catchers as well as for supplying a division of torpedo-boats. Cost of each $142,800.

The Germans have realized the fact that their seas are well suited for torpedo-boat defense, and have devoted much attention to the training of their personnel. At first their boats met with the usual casualties to boilers, the tubes and the linings of fireboxes burning out, but with experience their firemen have learned to tend the fires so intelligently that such injuries no longer occur.

This was strikingly shown during the manœuvres from May 1 till October, 1888, when sixteen Schichau boats and two division boats were constantly together manœuvring, and but one accident happened—the breaking of a propeller—which was of sufficient moment to necessitate return to the dock-yard.

The flotilla is divided into ten divisions, each consisting of eight torpedo-boats and one division boat. Five divisions are stationed at Kiel and five at Wilhelmshaven ready for mobilization. The other boats stationed along the coast can be mobilized as the occasion may require.

The division boats have been found useful. They act as the flag-ships, and are fitted to make small repairs, to carry all necessary supplies, and to afford accommodations for the staff officers required for the service of the flotilla.

HOLLAND.

The *Cerberus*, built at Flushing, has a displacement of 83 tons, a draught of 4 feet 7 inches, a speed of 22¾ knots. She is to be stationed at Soerabaya, Java.

Three others building, of the same dimensions as the *Cerberus*, are likewise destined for the Indian Netherlands.

The *Empong*, of the English No. 79 type, completed by Yarrow in 1888, is 125 feet long, 13 feet beam, and 6 feet 2 inches draught. All the latest improvements (see page 440) in torpedo-boat construction have been embodied in her. The engine is of the triple expansion type, and is capable of developing 1,200 horse-power. The torpedo armament consists of a pair of torpedo-tubes for direct fire ahead, and it is also expected that a double divergent tube will be placed aft. On the first trial, with a load of 16½ tons, a mean speed of 22.8 knots was made during a two-hour run. On the second trial, of one hour's duration, and carrying a load of 7 tons, 24.1 knots were made.

The *Foca* and *Goentor* were commenced at the Government dock-yard, Amsterdam, in 1887.

The *Habang* was commenced in 1888 by the Royal Steam Engineering Works at Amsterdam.

ITALY.

The *Aquila*, *Avvoltoio*, *Falco*, *Nibbio*, and *Sparviero*, twin-screw sea-going torpedo-boats, have been built and were delivered by Schichau in 1888. They are 152 feet 6 inches long, their breadth of beam is 17 feet, and their displacement 130 tons. They have two triple-expansion engines with an I. H. P. of 1,800 to 2,000, and two locomotive boilers. The coal capacity is 42 tons and the radius of action 4,000 miles at 10 knots. Maximum speed, 25 knots. The armament consists of two 37 mm. Hotchkiss R. F., two 57 mm. Hotchkiss R. F., one 37 mm. Hotchkiss R. C., one built-in-stem tube, air impulse, two turn-table tubes abaft, gunpowder impulse, and nine 14-inch Schwartzkopffs. Cost of each boat, $88,000. Probably this sum does not include the artillery and torpedoes.

First-class 39-metre boats Nos. 109, 110, 111, 112, 113 have also been built and delivered by Schichau. They differ from the 39-metre type described further on only in their torpedo armament, which consists of two built-in-bow tubes.

The 39-metre Schichau type.—All first-class boats built since 1886 are of the Schichau type. Sixty of this type have already been built, partly by Schichau, of Elbing, Germany, and partly by domestic firms. Their dimensions are as follows: Length, 127 feet 10 inches; beam, 15 feet 8 inches; displacement, 75 tons; draught forward, 2 feet 5 inches; aft, 6 feet 6 inches.

The latest built have eight water-tight compartments, and in the compartments forward and aft for the accommodation of the complement half bulkheads rising 19 inches above the water-line. There is an equipoise rudder aft and a similar one forward. Both may be worked by steam or hand steering gear in the towers. The forward rudder may be raised or lowered. The conning towers are elliptical, 4 feet 7 inches high, 6 feet 6 inches broad, and 4 feet 7 inches long. A 37$^{\mathrm{mm}}$ Hotchkiss R. C. is mounted on each. Both towers are in telegraphic communication, externally and internally, with each other and with the engine-room. There is also speaking-tube communication. The engines are triple expansion, with cylinders, 15.7, 24.8, and 35.4 inches in diameter. Stroke, 35.4 inches; I H. P., 900 to 1,000. The screw is single. The boiler is of the locomotive type, with a grate surface of 43 square feet and a heating surface of 1,938 square feet. Partial coal protection is afforded by the bunkers on each side. Their capacity is 18 tons, and they are water-tight. The torpedo armament consists of one built-in-stem tube of 14 inches interior diameter and 16 feet 6 inches length, air impulse, one turn-table tube aft, gunpowder impulse, and four 14-inch Schwartzkopffs.

This torpedo is 13.98 inches in diameter, 15 feet 5 inches long, and weighs 605 pounds. The charge consists of 125 pounds of gun-cotton.

The speed required is 19½ knots during a three-hour run in calm weather over a smooth sea.

Twelve of these boats were ordered in January and February of this year. Nos. 112, 113, 114, 115, to be built by Pattison & Co., Naples; Nos. 116, 117, 118, 119, to be built by Cravero, Genoa; Nos. 120, 121, 122, 123, to be built by Odero & Co., Sestri, Ponente.

It is stated that during the naval manœuvres in 1888 the *Avvoltoio* class did not prove so satisfactory as the 39-metre boats. Structural strength, seaworthiness, and the comfort of the complement were found to have been sacrificed to attaining a speed which was greater than that of the 39-metre boats only in smooth water. In rough weather it became necessary to batten down the hatches of the larger boats, and the complements were quickly exhausted by breathing foul air and by the continued motion, and the torpedo-tubes were rendered unserviceable, whereas under the same conditions of weather the hatches of the 39-metre boats were kept open, the crews were comfortable, and the torpedo-tubes could have been used at any time.

It is stated that six first-class boats, No. 63 (Pattison & Co.), No. 67 (Guppy), No. 71 (Cravero), No. 73 (Odero), No. 90 (Ansaldo), No. 106 (Schichau), made a long trip for the purpose of determining their sea-going qualities. The trial resulted satisfactorily for all except No. 106. A severe accident happened to the engine of that boat after an hour's run, which necessitated her withdrawal.

ROUMANIA.

The Forges et Chantiers de la Méditerranée at Havre delivered in September, 1888, to the Roumanian Government, three first-class torpedo-boats, the *Naluca*, *Sineul*, and *Sborul*. Extreme length, 120 feet 8 inches; length at water-line, 114 feet 9 inches; extreme breadth, 11 feet 4 inches; depth from deck to keel, 7 feet 9 inches; mean draught, 6 feet 9 inches; displacement, loaded, 55 tons. The engine is triple-expansion, and of a type which is said to be very economical of fuel. Diameters of cylinders, 12, 17.5, 26.7 inches: length of stroke, 14.8 inches. Single screw of bronze, with a diameter of 6 feet and a pitch of 6 feet 8 inches. The boiler is steel, of the locomotive type, with iron furnaces. The heating surface is 947 square feet. There are two rudders—an equipoise aft, and the usual type of forward rudder fitted for raising and lowering. There are three masts, which may be easily taken down, fitted with lugsails. The armament consists of two bow-tubes, Canet type; one spar-torpedo, and one 37^{mm} Hotchkiss R. C. The contract called for a speed of 20 knots with armament complete and 2,000 kilos (1.96 tons) of coal. The official trial was made in a rough sea. The boat proved seaworthy, and even at 21 knots, the maximum speed, no vibrations were felt.

Speed.	Revolutions.	Kilos of coal per knot.
21	332	23.8
15.27	239	12.28
12.67	187	7.5
10.99	168	5.46

Radius of action, 1,800 miles with the normal coal supply.

RUSSIA.

Six boats have been ordered this year—four first-class boats for the Baltic of 80 tons displacement, and two boats of 130 tons for the Black Sea.

The following boats (probably two of the above) have been ordered from F. Schichau. One 39-metre (127.9 feet) torpedo-boat; speed, 21 to 23 knots; triple expansion engine of 900 to 1,000 I. H. P. One twin-screw boat for torpedo and despatch service; maximum speed, 26½ knots.

A second-class boat, 60 feet long and 8 feet 6 inches beam, has been built by Yarrow for the Russian Government. The type is that adopted by the British Admiralty, and is intended to serve as tenders for large war ships or for harbor and coast defense. The description has already been given on page 400, No. VII. The official trial took place in September, 1888, in the Thames, when a speed of 17.58 knots was made during a continuous run of two hours. Circles to port and starboard at full speed were made in forty-five and fifty-nine seconds, respectively. The trials were satisfactory to the Russian officials.

SPAIN.

Only two second-class boats have been reported in course of construction. These were building at Cadiz in August, 1888.

EXERCISES OF TORPEDO-BOATS.

Torpedo-boats composing the flotilla.

Name.	Builder.	Date of completion.	Length.	Displacement.	Acceptance speed.
			Feet.	*Tons.*	*Knots.*
Acevedo	Thornycroft	1886	120	63	20. 1
Ariete	do	1887	147	120	26. 0
Azor	Yarrow	1887	134	100	23. 04
Barcelo	Normand	1886	126	66	19. 5
Habana	Thornycroft	1887	127	67	21. 0
Halcon	Yarrow	1887	135	108	23. 5
Ordoñez	Thornycroft	1885	120	65	20. 16
Rayo	do	1887	147	120	24. 63
Retamosa	Yarrow	1886	118	70	20. 02

These torpedo-boats, belonging to the departments of Cadiz, Ferrol, and Carthagena, were ordered to assemble at Carthagena for the purpose of testing their armaments and manœuvring.

Several casualties happened on their way to the point of rendezvous:

On April 5, 1888, an accident happened to the boiler of the *Habana*, described in No. VII, page 406, which prevented her further participation in the manœuvres.

While towing the *Habana* an accident happened to the air-pump of the *Ariete* which necessitated the latter's putting into Corcubion.

When the *Ariete* joined the flotilla, on May 16, one boiler was disabled. With the other she could maintain a speed of 18.4 knots.

The *Retamosa* arrived on May 3 and was obliged to go to the arsenal to replace her propeller, a blade of which had been bent.

TORPEDOES.

The flotilla was equipped with the Schwartzkopff torpedo, each boat carrying four. The tubes are built in the bow, one on each side of the stem parallel to keel, and fitted for air impulse with a cartridge charged to 4 or 4½ atmospheres. The *Azor* has additionally a double-divergent tube aft.

The defects developed in the torpedoes during practice are classified as follows for clearness:

Indentations, missing screw, or bent rods, defects quickly remedied and which would not prevent the discharge of the torpedo, are enumerated in column *a*.

Fracture, bending, or such internal disarrangement as would disutilize the torpedoes for discharge and which would necessitate repair at the workshops are enumerated in column *b*.

	Shots.	*a*.	*b*.
Ordoñez	12	......	1
Acevedo	10	......	....
Barcelo	8	......	....
Retamosa	6	......	....
Ariete	10	1	....
Rayo	10	......	1
Azor	8	1	....
Halcon	11	......	1
	75	2	3

The damage referred to in column *b* happened in the following ways:

Ordoñez.—Through the failure of the throttle-valve to close, the torpedo went ashore.

Rayo.—The torpedo itself was of defective construction. At each discharge the skin of the sinking compartment showed deformation, owing to the impulse of the propellers.

Halcon.—Through the retention of the torpedo in the tube at discharge.

Seventy-five per cent. of the discharges were hits, and of the torpedoes discharged six were ejected simultaneously in pairs.

There were thirty-two torpedoes used, and throwing out of consideration the defective torpedo belonging to the *Rayo*, the proportion to which serious damage happened was only 6 per cent.

For the purpose of testing the efficiency of the torpedoes when discharged from an unsteady platform, a day was chosen with a heavy swell from east. The *Ariete*, 120 tons, and the *Retamosa*, 69 tons, steaming into a head sea, made excellent practice. Two torpedoes, discharged when the boats were running at a speed of 14 knots into a head sea, traversed straight trajectories; discharge from the *Halcon*, with the sea abeam, while rolling 25 to 30 degrees, was equally satisfactory.

During all the practice, air compressors, air cartridges, the tubes and their appendages gave entire satisfaction. It was found that under ordinary circumstances from eight to sixteen minutes were necessary to charge a tube with a torpedo brought from the torpedo room.

SEARCH LIGHTS.

All the torpedo-boats of the flotilla were equipped with search lights and electric illumination. The following conclusions as to the value of the search lights were reached after a long course of exhaustive experiments:

At anchor in port, the light being directed on the Castle St. Julian, 2,540 metres distant, the outer breakwater 1,400 metres distant, and the inner breakwater 950 metres distant, those objects became easily visible to the flotilla; even the white gravel used in their construction was distinguishable.

At sea, objects surrounding the Castle St. Julian appeared much blurred; details were indistinguishable. The luminous arc resembled a brilliant mist, which was spread over a large field, owing to the position of the projector near the water. The light reflected from the deck diminished the range of vision in the luminous arc, and imparted to the rest of the horizon an aspect of impenetrable obscurity.

The light projected coastward or seaward never discovered the presence of a torpedo-boat, even though its cruising ground was known. On the other hand, it never failed to betray the presence of the torpedo-boat using it.

The difference in the visibility of objects from a boat in port and at sea is attributable only to the condition of the platform as to steadiness.

The electric projectors that were used were of 7,500 candle-power. Their field is limited, and their range at sea is from 600 to 800 metres, depending on the state of the atmosphere.

Experiments at sea have also demonstrated the difficulty of focusing quickly, and of following a rapidly-moving object.

As a result of the above conclusions, the use of the electric light is to be discontinued on torpedo-boats, and its application to other purposes than searching for an enemy is to be replaced by blue lights and Drummond rockets.

ARTILLERY.

The *Ordoñez*, *Acevedo*, *Barcelo*, and *Retamosa* were the only boats armed. Towards the end of the exercises the four remaining were supplied with ten Remington rifles.

On May 12, with fresh breeze from east and a swell which caused her to roll 15 to 20 degrees, the *Ordoñez* carried out practice with her 25^{mm} Nordenfelt machine-guns, using for a target a quarter cask anchored at a range of 546 yards. The firing was very deliberate on account of the rolling.

	Shots.	Marksmen.	Hits.
Ordoñez	10	2	0

On May 18 and 19 small-arm practice was held, using a target 5.2 feet high and 1.9 foot broad. The range for the first three shots was 328 yards and 437 yards for the remaining.

	Shots.	Marksmen.	Hits.
Ordoñez	28	9	5
Acevedo	31	9	4
Barcelo	45	9	3
Retamosa........	45	9	2
	149	36	14

Nine per cent. of the shots were hits.

On June 21 practice was held under the following conditions: The target represented a section of torpedo-boats; width, 65.6 feet; height, 3.2 feet; depth, 4.4 feet. It was lined with iron plating .19 inch thick.

In its centre a bunker was placed containing a ton of coal and two loaded torpedo heads, one on each side. The bunker was lined with iron plating .19 inch thick, and was of the following dimensions: Width, 6.56 feet; height, 2.6 feet; depth, 2.7 feet.

The *Halcon* took a position in line with the boats and the target, for the purpose of illuminating the latter with her projector.

The conditions were unfavorable for the torpedo-boats. A southwest swell caused them to roll 20 to 25 degrees, and prevented the *Halcon* from bringing her projector to bear on the target except at intervals. Range, 656 yards; duration of fire, five minutes.

	Artillery.	Shots.					Remarks.
		No.	Projectiles.	Per minute.	Hits.	Per cent.	
Rigel	I 37$^{\text{mm}}$ H. R. C	10	Shell	2	1	10	
Barcelo	II 25$^{\text{mm}}$ N*	130	Lead 34 Steel 96	3	2	1.5	Both hits were allowed each torpedo-boat
Retamosa	do	240	Lead 120 Steel 124	3		.8	

* Nordenfelt.

Owing to the arrangement of her machine-guns, the *Barcelo* could fire both her machine-guns together only at intervals.

One hundred and fifteen shots were fired from small-arms on the *Barcelo* and *Retamosa*. Only three hits were made.

On June 23d practice was continued from the *Rigel* and *Retamosa* at 382 yards. The sea was smoth and the rolling was only 5 degrees.

	Artillery.	Shots.			
		No.	Kind.	Hits.	Per cent.
Rigel	I 37$^{\text{mm}}$ H	33	Shell	7	21
Retamosa	II 25$^{\text{mm}}$ N	418	Lead 212. Steel 206.	62	15

On both days the 37$^{\text{mm}}$ Hotchkiss made a larger per cent. of hits than the 25$^{\text{mm}}$ Nordenfelts. This may be due in part to the mounting of the former, which permitted more accurate pointing. The following are the heights of the guns above the water line:

Vessel.	Artillery.	Height.
		Feet.
Rigel	H. R. C.	9
Barcelo	N.	7
Retamosa	N.	7.6 9.3

The study of the target leads to the following conclusions:

The outer iron plates of .19 inch thickness showed no breaks or cracks, the projectiles passing through them invariably.

Six projectiles entered the bunker and penetrated the following distances into the coal:

Steel projectile, 25 mm., intact	feet	2
Steel projectile, 25 mm., intact	do	1.3
Steel projectile, 25 mm., intact	do	1.9
Lead projectile, 25 mm., completely deformed	do	1.3
Lead projectile, 25 mm., completely deformed	do	1

Hotchkiss shell, 37 mm., H. R. C., fragments were found in the coal.

Coal protection, 2.7 feet thick, closely packed, offers effective resistance to the passage of the above-mentioned projectiles.

Six shots passed through two .19-inch iron plates, 2.7 feet apart.

The lead bullets were flattened in passing through the plate.

Laying off on the target a space equal to the bulkhead of compartment No. 2 of the *Ordoñez*, that area would include five shots, which make circular holes of 1.7 inches average diameter. Supposing the boat to be lying still, the amount of water admitted would be 18.5 tons per hour, but as the capacity of the ejector of this compartment is 40 tons per hour, the water could be ejected more rapidly than it could enter.

Steel projectiles from the Nordenfelt machine gun of 25^{mm} at 656 and 382 yards will traverse both sides of a torpedo-boat, or one side and a bulkhead .098 to .118 inch thick.

Remington bullets make indentations only on the target.

Coal protection is efficient and of such value to the boilers and engines as to warrant its adoption even at the expense of other qualities.

TURNING QUALITIES.

The eight torpedo-boats were fitted with rudders as follows:

The *Ariete* (T.) * and *Rayo* (T.) with twin stern rudders.

The *Halcon* (Y.),* *Azor* (Y.), and *Retamosa* (Y.), with a stern and bow rudder. The *Halcon's* stern rudder was placed before and the *Azor's* and *Retamosa's* abaft the propeller.

The *Barcelo* (N.),* the *Ordoñez* (T.), and the *Acevedo* (T.), with bow and stern rudders.

The following results were obtained with the four smaller boats:

Vessel.	Builder.	Length.	Displacement.	Time of turning.	Remarks.
		Feet.	*Tons.*	*m. s.*	
Ordoñez	Thornycroft	120	65	1 10	Using both rudders.
Acevedo	do	120	63	1 10	Do.
Barcelo	Normand	126	66	50	Do.
Retamosa	Yarrow	118	70	1 02	

Tactical diameters to port and starboard are not the same, depending on the effect of the thread of the screw.

Lesser tactical diameters are obtained with speeds reduced to 8 or 10 miles.

The combined action of both rudders reduces the tactical diameter, but the speed is thereby diminished 1.5 to 2 miles; the angle of the two rudders with the line of keel is 20 to 25 degrees.

The servo-motor is of great value, reducing considerably the time of reversing the helm.

Going astern there is no rudder effect; the tendency is for the stern to come up into the wind.

Time from going ahead to going astern, ten to fifteen seconds.

The *Ariete* and *Rayo* yaw considerably when struck by a sea on the bow or quarter, owing to their cutaway keels.

SPEED TRIALS.

On June 6 the boats were tested for speed in a race from Escombrera Island to Alicante, a distance of 68 miles.

The course paralleled the trend of the coast. From Escombrera Island to Cape Palos the boats encountered a fresh breeze from the east and a head sea, which was at times thrown over the funnels, making a lookout ahead difficult. During the latter part of the race, from Cape Palos to Alicante, the sea was smooth and the wind light from southeast.

---

* N = Normand. T = Thornycroft. Y = Yarrow.

	Builder.	Displacement.	Date of acceptance.	Speed.	
				Acceptance.	June 6, 1888.
		Tons.		*Knots.*	*Knots.*
Barcelo	Normand	66	1886	19.5	19.7
Ariete	Thornycroft	120	1887	26	17.2
Halcon	Yarrow	108	1887	23.5	19.6
Rayo	Thornycroft	120	1887	24.63	19.6
Ordoñez	do	65	1885	20.16	16.1
Acevedo	do	63	1886	20.1	15.8

The *Azor* dropped out early in the race, owing to an accident to her machinery, which obliged her to proceed at a moderate speed.

Belmes coal, which had been freed from dust by sifting, was used.

The speed of the *Ariete* is noteworthy as being made under one boiler. Her sister, the *Rayo*, also fitted with the tubulous boilers, could raise a steam pressure of only 105 pounds, the pressure required for development of maximum speed being 150 pounds.

On arrival at Alicante the boiler of the *Acevedo* was found to have a large number of leaky tubes and two stays showing signs of distress. It was considered safe, however, to return next day to Cartagena at a speed of 8 to 10 knots.

The boiler of the *Ordoñez* also showed signs of weakness.

The machinists and firemen were so exhausted at the conclusion of the race that the return of the torpedo-boats was delayed until the next day.

TURKEY.

It is reported that the Turkish Government has lately ordered three torpedo-boats and six torpedo catchers from the firm of Schichau at Elbing.

In January, 1889, two boats built at the Germania Works made satisfactory trials in the presence of Turkish officials. Three others were launched earlier in the month.

It is reported that in November, 1888, a torpedo-boat built at Constantinople with the assistance of German workmen, was launched, and that in August, 1888, a second-class boat of domestic construction performed satisfactorily on trial.

UNITED STATES.

Torpedo boat No. 1, building by Herreshoff, of Bristol, R. I., has already been described on page 407, No. VII. It will be ready for trial within a few months.

SUBMARINE BOATS.

Several bids were made in February, 1889, for the construction of a submarine boat for the United States, but owing to the cost of the coast defense vessel, which exceeded the estimate, there was not a sufficient balance left from the appropriation which was to have been applied to both projects, and the intention of the Department with regard to building the submarine boat this year was given up.

THE GYMNOTE.

The plans of this boat were submitted in October, 1887, by the Forges et Chantiers de la Méditerranée, and accepted by Admiral Aube. The designer is M. Zédé, engineer-in-chief of that company. The boat was built under the supervision of M. Romazotti at the Mourillon dock-yard, Toulon, where she was launched on September 15, 1888.

The shape is like that of the Whitehead torpedo. Length, 59 feet; greatest diameter, 5 feet 11 inches; displacement, 29.5 tons. Like the Whitehead, the *Gymnote* has two horizontal rudders worked by hydrostatic pressure or at will, and two vertical rudders worked by the usual appliances.

The power is electricity. The boat is steered, propelled, and lighted by this agent, which is supplied by a battery of 564 alkaline accumulators invented and manufactured by MM. Commelin, Desmazures, and Bailhache. Each accumulator weighs 38.5 pounds. The weight of the battery is therefore 9.66 tons. The motor gives 60 H. P. with the normal current of 220 ampères at 220 volts. One H. P. consequently is given off per 360 pounds of battery.

The motor is the invention of Captain Krebs. It consists of 16 poles arranged around a ring armature one metre in diameter. Its weight is 4,400 pounds. The propeller is four-bladed, 4 feet 10 inches in diameter. The shaft connects directly with the armature which works the screw at two hundred turns per minute. The estimated speed is 10 knots for six hours.

The specific gravity is varied by admitting or expelling water from the tanks.

Air compressed in reservoirs is supplied as required for breathing. During the trials it was found that four men could live under water about four hours without having recourse to the supply.

The kind of armament has not yet been decided on.

Price of hull, $10,422; accessories of hull, $5,790; machinery and motive power, $17,370. Total, $33,582.

On November 17, 1888, two two-hour trials were made at the entrance to Toulon, in the presence of Vice-Admiral Duperré, Prefêt Maritime of the port. The boat dove to 7 metres and ran 500 metres at good speed. While under water no trouble in breathing was experienced; the boat rolled slightly, the engines worked quickly ahead or astern, the rudders functioned perfectly.

It is stated that the estimated speed was not obtained owing to the leakage of electricity. Actually, the speed submerged did not at any time exceed 4 knots per hour, and on the surface it was at no time greater than 6 knots.

A compass was used for maintaining direction under water, but its indications were found to be entirely untrustworthy, being at times nearly 16 points in error.

The *Gymnote* is an experimental boat in every sense, and defects developed by trial are not so likely to become known as the good points, still the general opinion seems to be that the features of the type are so promising of improvement as to be worth experimenting with in a boat of larger dimensions.

THE PERAL.

The *Peral*, so named after the inventor, Lieutenant Peral of the Spanish navy, was launched on September 8, 1888, at the Carraca dock-yard, near Cadiz. Her construction had been begun in October, 1887.

The shape is similar to the Whitehead, but the cross-section is ogival. Length, 72 feet; maximum diameter, 9 feet 6 inches; displacement, 86 tons; draught of water when floating on the surface, 2 feet 11 inches.

There are six hundred and thirteen accumulators, and at the first charging several days were required for that operation. The slowness of charging was attributed to the machinery being out of order. But even under the most favorable conditions it is expected that at least eighteen hours will be required for that operation. One hundred and twenty-five accumulators are apportioned to each of the screw-motors, which develop 30 horse-power each; one hundred accumulators vitalize the pump motors, and the remainder supply a very powerful electric projector and other apparatus of secret design. The greatest secrecy is maintained by the Spanish officials in regard to every detail.

The armament will consist of Whitehead torpedoes to be discharged from two bow tubes. The complement, six in all, consists of four lieutenants, a machinist, and a quartermaster.

The estimated speed at the surface is 11 knots, and 10½ knots submerged.

It is stated that the air supply is sufficient to enable the crew to remain under water two days, and that there is a device for purposes of observation when running near the surface, probably a camera lucida.

A trial was attempted on March 6, 1889, at the Arsenal de la Carraca. The boat got under way at 11 a. m. and proceeded a short distance at the rate of about 6 miles an hour, when she was obliged to stop owing to a defect in the port propeller motor. It is reported that the defect was trifling and would soon be remedied, but no account has appeared of any trial since.

THE GOUBET.

The hull is of cannon bronze. It was made in one casting which weighed 5 tons. The finished hull weighs 2.65 tons. Its length is 18.37 feet, and its maximum diameter 5 feet. Oxygen is supplied for breathing. It is compressed at a pressure of 70 atmospheres in steel tubes 3.93 feet long, 4.72 inches diameter, weighing 66 pounds. This supply is calculated to afford perfect aeration for fifty hours.

The first official trial of the *Goubet* was made at Cherbourg in May, 1889, to test its system of aeration. It is reported that two men, constituting the crew, were hermetically inclosed in the hull for eight hours, the boat being submerged to a depth of 33 feet, and the only communication with the surface being telephonic. At the end of the experiment the men were found to have experienced no discomfort, and there remained sufficient oxygen to have prolonged the experiment twenty-five hours and more.

A FRENCH SUBMARINE BOAT BUILDING.

In November, 1888, the French Government gave an order to the Compagnie Générale des Bâteaux Parisiens for the construction of a new submarine boat to be used for destroying submarine mines. The boat is building at Toulon. Her length as stated by one source is 11.8 feet, and by another 14.9 feet; the diameter is 5 feet 4 inches. Complement, two men. Air will be provided from stores of compressed oxygen, permitting a stay of several hours below the surface. The screw is turned by a motor supplied with electricity by a Schanschieff primary battery. The interior is to be lighted with five 8-candle-power incandescent lamps. An arc light projector is to be fitted.

RUSSIAN SUBMARINE BOATS.

In Russia three submarine boats will soon be finished. The greatest secrecy is being observed with regard to the features of their construction.

J. T. Newton,
Lieutenant, U. S. Navy.

THE MANŒUVRING POWER OF OCEAN STEAMERS.

Through the Hydrographic Office and its branches the Office of Naval Intelligence has forwarded inquiries to the captains of various ocean steamers entering United States ports with the object of gaining information in regard to their manœuvring power. For this purpose the following questions were asked:

(1) Steaming ahead, how long does it take to change course four points after the order is given to put the helm hard over?

(2) Steaming ahead, how long does it take to change the course eight points after the order is given to put the helm hard over?

(3) What is the nature of your steering gear, steam or hand?

(4) Steaming ahead full speed, how long does it take to lose headway (stop dead in the water) after the order to stop and back is given?

(5) Any other information on this subject would be desirable.

In order not to make the difficulty of answering the questions so great that it would interfere with the accuracy of the information obtained they were made fewer in number and simpler in character than would otherwise be desired. The answers to these questions are put in tabular form, and the Office is indebted to the captains of the steamers for the interest they have shown in answering the questions and in making experiments to obtain the desired information.

Under the direction of the British Association experiments have been performed with certain ocean steamers, and from this and other sources a general knowledge has been obtained in regard to manœuvring powers, but steamers differ so greatly in character and the conditions under which they manœuvre are so variable that any rules are necessarily very general in character. The information here obtained from various sources will serve to show within what limits dependence can be placed upon any general rules.

In a great many cases from which reports have been received experiments were performed and the manœuvres accurately timed. In others the times of the manœuvres have been estimated, but they are sufficiently accurate to afford useful data. These estimates are generally less than would probably be found by actual trial. The estimates as to the distance advanced before coming to a dead stop after reversing the engines are also much less than in similar cases where the distance has been measured. Thus, the *Manhattan*, a steamer of 1,525 tons, from a speed of 11.5 knots came to a dead stop in two minutes and forty-five seconds, during which she advanced 600 yards as measured. This advance is about eight times her length and is six-tenths of her advance in the same time at her original speed. With similar ships which required even a greater time to come to a dead stop from an original speed of 12 knots, the advance as estimated in a number of cases was only one and one-half times the ship's length and only about one-sixth of the distance they would have advanced in the same time by maintaining the original speed. Probably a few ships only are able to come to a dead stop in less than three times their length, or than one-third the advance in the same time at original speed. As this tendency to underestimate both the time and distance of manœuvres appears from the reports to be somewhat general, it may be inferred that the manœuvring power of ocean steamers is not as great as is generally supposed.

The additional information received in answer to question 5 is nearly all of a general character, pointing to the fact that the manœuvring power of any vessel is affected by the state of the wind and sea and the heading of the vessel in regard to them. This effect varies according to the trim of the vessel and whether she is loaded or in ballast, and an idea of its amount may be gained from the result of experiments detailed further on. Most vessels lose steerage way as soon as the propeller is turned astern, and with a right-handed screw the ship's head will fall off to starboard. Some captains of steamers declined to make the experiment of reversing from full speed on account of the danger from bringing such a strain upon the propeller shaft. They were unwilling to perform such a manœuvre, except in case of emergency. In reversing the engine from full speed ahead, before coming to a dead stop, the *City of Augusta*, *Lake Huron*, and *Tallahassee* changed heading six points to starboard, the *Cragside* seven and three-quarter points, the *Ethiopia* four points, and the *Seneca* changed heading two points to starboard against starboard helm, wind and sea.

S. S. *Excelsior:* "My experience is that the instant you commence to back a ship when she is going ahead the helm has no effect until after the ship gets sternboard, and then the helm has more effect when half over than when hard over."

S. S. *Alvo:* Loses steerage way the instant the propeller is turned astern and her head falls off to starboard.

S. S. *Seneca:* 2,735 tons, 2,300 indicated horse-power, 280 feet long, no keel; broad rudder and flat midship section, was built to combine the greatest carrying capacity with ability to manœuvre in narrow channels. Capt. R. B. Quick writes: "I had previously notified the engineer. Ship was steaming at full speed, 14.75 knots, with sixty-seven revolutions of the engines. The course was NW., with moderate wind and small sea from N. Rang to stop and back full speed and at the same time ordered the helm hard a-starboard. In one minute and thirty seconds the ship was stopped dead in the water with her head at NNW. The distance ran, judging by the pilot boat, which was ahead of us, was from 350 to 400 yards. The ship was half loaded."

S. S. *Trinidad:* "Loses all steerage way after the first turn of the propeller astern."

S. S. *Zealandia:* "As soon as the engines commence to back the steering of the vessel is out of the question, swinging her bow off to starboard no matter how the helm is put."

S. S. *Wyoming:* "Steaming ahead full speed after the order to go astern full speed, the ship lost steerage way in one minute and ten seconds, and lost all headway in two minutes and forty seconds."

S. S. *Denmark:* "In reversing engines steerage way is lost immediately."

The amount that steamers forge ahead varies more than the times in which they can turn. From the original speed and the time required to bring the steamer to a dead stop a rough estimate may be made of the distance advanced. It appears that this distance with the vessels tabulated varies from three and one-half to ten or twelve times the vessel's length.

Nearly all vessels heard from possess steam steering gear. The S. S. *Buffalo* requires ten seconds, the S. S. *State of California* twelve seconds, and the S. S. *Seneca* fifteen seconds to put the helm hard over from amidships with steam steering gear. The S. S. *Mexico*, with hand steering gear and one man at the wheel requires thirty-seven seconds, and with two men at the wheel thirty seconds to put the helm hard over from amidships.

S. S. *Pueblo*, in ballast, with a draught of 12 feet 8 inches forward and 17 feet 8 inches aft, turns as follows: With port helm, four points in one minute and forty seconds and eight points in three minutes and five seconds; with starboard helm, four points in one minute and twenty-two seconds, and eight points in three minutes and eight seconds. When loaded with a draught of 18 feet 7 inches forward and 20 feet 5 inches aft she turns with port helm four points in two minutes and twenty seconds and eight points in four minutes and fifteen seconds; with starboard helm she turns four points in one minute and forty seconds and eight points in three minutes and ten seconds.

The experiments of Capt. J. N. Ingalls with the S. S. *Santa Rosa* and the S. S. *Corona* shows the turning powers of these vessels under varying conditions:

Santa Rosa:	m.	s.
Ship light, calm, sea smooth, turns 4 points in	1	00
Ship light, calm, sea smooth, turns 4 points in	0	45
Ship partly loaded, calm, sea smooth, turns 4 points in	1	05
Ship partly loaded, calm, sea smooth, turns 4 points in	1	10
Ship partly loaded, gentle breeze and sea, turns 4 points in	1	10
Ship partly loaded, gentle breeze and sea, turns 4 points in	1	00
Ship partly loaded, moderate breeze and sea, turns 4 points in	1	10
Ship partly loaded, fresh wind and rough sea, turns 4 points in	1	25
Ship in ballast, light breeze, smooth sea, turns 8 points in	1	55
Ship in ballast, light breeze, smooth sea, turns 8 points in	2	00
Ship partly loaded, light breeze, smooth sea, turns 8 points in	2	10
Ship partly loaded, gentle breeze and sea, turns 8 points in	2	10
Ship partly loaded, fresh wind, rough sea, turns 8 points in	2	15
S. S. *Corona:*		
Ship light, calm, smooth sea, turns 4 points in	0	45
Ship light, moderate wind and sea, turns 4 points in	1	00
Ship light, gentle wind and sea, turns 4 points in	1	45
Ship loaded, from slow speed, turns 4 points in	1	30
Ship loaded, from good headway, turns 4 points in	1	00
Ship light, light breeze, calm sea, turns 8 points in	1	30
Ship light, gentle wind and sea, turns 8 points in	2	00
Ship loaded, gentle wind and sea, turns 8 points in	2	30

With steam steering gear the time required to turn through the first point after the order is given to put the helm over is about double that of any succeeding point. After this the time of turning is practically uniform.

The S. S. *Westmoreland*, course N. 75° W., light breeze W. N. W., moderate N. W. swell, speed 13.5 knots, turned as follows with port helm:

	m.	s.		m.	s.
1 point in	0	32	5 points in	1	36
2 points in	0	46	6 points in	1	54
3 points in	1	03	7 points in	2	09
4 points in	1	20	8 points in	2	25

With starboard helm and a speed of fourteen and one-half knots she turned—

	m.	s.		m.	s.
1 point in	0	35	3 points in	1	02
2 points in	0	47	4 points in	1	17

The S. S. *Buffalo*, with moderate N. W. wind and smooth sea, speed 12 knots, course E., with port helm turned as follows:

	m.	s.		m.	s.
4 points in	1	30	20 points in	7	00
8 points in	2	45	34 points in	8	15
12 points in	4	00	28 points in	9	15
16 points in	5	45	32 points in	10	00

The octants were swung as follows: First, in one minute thirty seconds; second, in one minute fifteen seconds; third, in one minute fifteen seconds; fourth, in one minute forty-five seconds; fifth, in one minute fifteen seconds; sixth, in one minute fifteen seconds; seventh, in one minute; and eighth, in one minute forty-five seconds. It will be observed that in swinging through the fourth and eighth octants the ship was broadside to a moderate wind. This was the case with the S. S. *Ethiopia* in the table having the wind and sea abeam in the second octant. With the S. S. *Buffalo*, stopped dead in the water, the order was given full speed ahead and helm hard aport, and the ship swung sixteen points in five minutes thirty seconds, and thirty-two points in nine minutes thirty seconds.

The S. S. *Manhattan*, in a calm and smooth sea, speed 12 knots, swung with—

Port helm:	m.	s.	Starboard helm:	m.	s.
4 points in	0	57	4 points in	0	54
8 points in	1	45	8 points in	1	31
12 points in	2	30	12 points in	2	04
16 points in	3	19	16 points in	2	49
And a complete circle in	6	02	And a complete circle in	5	39

The S. S. *Guyandotte* swings through a complete circle in six minutes.

The effect of twin screws may be seen from the experiments of Captain Perry, of the S. S. *Richmond Hill*. This vessel is 430 feet long, 27 feet beam, and 4,126 tons; speed, 10.5 knots. Smooth sea and light breeze.

	m.	s.
To turn four points, both engines full speed ahead	1	13
To turn eight points, both engines full speed ahead	2	20
To turn four points, helm hard a-starboard, starboard engine going ahead, port engine stopped	0	55
To turn eight points, same conditions	2	05
To turn four points, helm hard a-starboard, starboard engine ahead full speed, port engine backing	1	14
To turn eight points, same conditions	2	00

With one engine backing, the time required to turn through eight points did not differ materially from the turning time with one engine stopped, but the space passed over was only about two-thirds as great.

Going ahead full speed the order was given to reverse the engines, and the ship came to a dead stop in two minutes forty-five seconds, and in three minutes forty-five seconds was going full speed astern.

Name of vessel.	Gross tonnage.	Length.	Beam.	Speed.	Port helm.		Starboard helm.		Direction of helm not indicated.		Nature of steering gear.	To lose headway.	Remarks.
					To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.			
	Tons.	*Feet.*	*Feet.*	*Knots.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*		*m. s.*	
Commonwealth	958	215	32						10	15	Hand	7 00 11 00	Light. Loaded; no keel.
Sir Garnet Wolseley	2, 239	292	37	10. 00	20	30					Steam and hand	3 00	Steam gear; time estimated.
Do	2, 239	292	37		1 30	2 00					do	3 00	Hand gear; time estimated.
Egyptian Monarch	3, 916	360	43						30	40	Steam	2 37	
Exeter City	2, 198	285	38	10. 00					38	1 28	do	4 00	
Llandaff	420	152	24						40	1 00	do	2 00	
Miranda	1, 158	220	31		40	1 05					do	17 00	Without reversing.
Baldar	1, 419	244	33						40	1 25	Hand	1 15	Ballast.
Oregon	2, 335	283	37		45	1 05	1 45	2 00			Steam		Moderate wind; light swell.
Peconic	1, 795	277	35						50	1 10	do	3 30	Without reversing; 10 minutes.
Robilant	5, 085	384	44						50		do	*10 00 †12 00	Without reversing.
Dalton	2, 039	315	35	10. 00	1 00	2 00					Steam and hand	2 00	Light; rough weather; head to wind and sea.
Do	2, 039	315	35	10. 00	50	1 30						4 00	Loaded; fine weather.
Tallahassee	2, 677	280	41		55	1 40	1 10	2 00			Steam	2 25	
Manhattan	1, 525	228	35	11. 5	57	1 45	54	1 31			do	2 45	
Taormina	2, 442	320	39						59	1 45	do	3 50 2 20	Loaded. Ballast.
Gutheil				9. 5	59	1 42	57	1 37				1 42	Flat bottom; no keel.

* Port. † Starboard.

Name of vessel.	Gross tonnage.	Length.	Beam.	Speed.	Port helm.		Starboard helm.		Direction of helm not indicated.		Nature of steering gear.	To lose headway.	Remarks.
					To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.			
	Tons.	*Feet.*	*Feet.*	*Knots.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*		*m. s.*	
Columbia	2,722	310	38	13.5	57	1 50	1 00	1 55	....	....	Steam	....	Moderate swell.
Denmark	3,724	342	42	....	....	....	....	....	1 00	2 00	do	....	
Cragside	1,974	284	38	....	....	....	....	....	1 00	1 30	do	3 30	
Stamford	515	172	25	....	....	....	....	....	1 00	1 35	Hand	1 40	
Portia	1,156	220	31	....	....	....	....	....	1 00	1 50	Steam	2 00 1 30	Loaded. Light.
Marcia	1,641	265	34	....	....	....	....	....	1 00	1 45	do	4 30	
Willamette	2,561	335	39	10.00	....	....	....	....	1 00	1 30	do	2 00	
Willamette Valley	844	205	34	....	....	....	....	....	1 00	1 30	do	2 00	
Old Dominion	2,223	250	42	....	....	....	....	....	1 00	1 30	Hand	....	Fresh wind.
Westernland	5,736	440	47	14.5	1 20	2 20	1 00	1 50	....	....	Steam	1 30	
State of Nebraska	3,986	385	43	....	1 00	2 05	1 10	2 00	....	....	do	3 00	Moderate wind; smooth sea.
Yorkshire	2,192	330	35	9.00	....	....	....	....	1 00	2 00	do	7 00 2 00	Loaded. Light.
Pennsylvania	3,104	343	43	12.00	....	2 20	1 00	2 10	....	....	do	2 20	Smooth sea; heavy ground swell.
Chattahoochee	2,676	280	40	....	1 05	2 01	1 17	2 13	....	....	do	....	
Seneca	2,729	271	42	14.00	....	2 30	1 00	2 40	....	....	do	1 30	Moderate breeze and sea.
Trinidad	2,162	270	37	....	1 05	....	....	1 25	....	....	....	....	
Chester	2,851	310	39	....	....	1 50	1 03	....	....	....	Steam and hand	3 00	
Nueces	3,367	328	44	....	1 09	2 10	1 02	2 14	....	....	Steam	10 00	Without reversing; fresh breeze.
Mexico	1,797	275	36	....	1 40	3 05	1 22	2 30	....	....	do	....	Strong wind and moderate rough sea.

Do	1,797	275	36		1 45	1 45	1 05	2 00			do		Calm, smooth sea.
Ethiopia	4,005	402	40	12.5					1 05	2 18	do	3 05	
Umatilla	3,078	310	40		1 30	2 45	1 05	2 00			do		
State of California	2,266	300	38	10.00	add 10 per cent.		1 30	2 30					
City of Augusta	2,861	323	40						1 10	1 40		3 00	
State of Georgia	2,489	330	36	13.00	1 10	2 25	1 03	2 13			Hand		Fine weather.
Guyandotte	2,351	267	40	13.00			1 10	2 00			do	3 00	Smooth sea.
Belair	1,419	244	33		1 10	2 03		2 35			Steam	2 50	Calm, light swell.
Wyoming	3,238	366	43	14.00					1 10	2 05	do	2 40	
Roanoke	2,354	265	40	13.00	1 12	2 02	1 28	2 28			do		
City of Richmond	4,780	440	44	14.5					1 15	2 45	do	2 45	
El Paso	3,531	351	43						1 12	2 15	do	6 00	
Queen of the Pacific	2,728	331	38		1 19	2 27	1 24	2 43			do		Smooth sea.
Westmoreland	1,384	240	32	14.5	1 20	2 25					Steam	3 00	
Alvo	2,009	292	34						1 20	2 00	Hand		
City of Alexandria	2,480	307	38		1 20			2 45			Steam	3 30	
Pedro	1,122	234	32		1 21	2 09	1 44	3 22			Hand	2 20	Ship light; propeller blade 4 feet out.
Werra	5,109	433	46	17.00			1 25				Steam		
Excelsior	3,264	330	42	12.75	1 26	1 59	1 26	1 59			do		
Buffalo	4,427	385	45	12.00	1 30	2 45					do		
La Bretagne	6,920	495	52	17.5	1 30	2 45					do	*2 00	15 knots, most efficient speed, turning quickly.
Ajax		221	33						1 30	1 35	Hand	2 10 3 00	Light. Loaded.
Villaverde	3,460			12.00	1 30	2 00	2 00	3 00				6 00	
Zealandia	2,730	377	37		1 30	3 00	1 25	2 40			Hydraulic		
Lake Huron	4,040	385	43	13.00					1 45	3 15	Steam	4 00	
Pontiac	1,745	267	33						1 30	2 15			
Jerome	1,090	213	29	12.00					1 30	2 45	Hand	3 00	
Viola	1,963	280	35						1 30	2 10	do	6 00	
City of Puebla	2,624	319	38		2 20	4 15	1 40	3 10			Steam		Left-handed propeller; calm, smooth sea.
La Champagne	6,800	493	52	17.5					1 40	2 30	do	5 00	

* Approximate.

Name of vessel.	Gross tonnage.	Length.	Beam.	Speed.	Port helm.		Starboard helm.		Direction of helm not indicated.		Nature of steering gear.	To lose headway.	Remarks.
					To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.	To change course 4 points.	To change course 8 points.			
	Tons.	*Feet.*	*Feet.*	*Knots.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*		*m. s.*	
Illinois	3, 102	342	43		1 54	3 25	1 40	2 53			do	4 30	Right-handed propeller.
Rhaetia	3, 553	351	43						2 10	3 43	do	2 10	
Biella	2, 182	316	35		2 00	3 40					do	2 30	
Minneola	2, 404	284	37	10. 5					2 15	3 30	do	4 45	
Richmond Hill	4, 126	430	27	12. 5			(*)					2 45	
Santa Rosa	2, 417	326	41				(*)						
Corona	1, 883	262	34				(*)						
City of Puebla	2, 624	319	38				(*)						Left-handed propeller.

* See text.

F. F. FLETCHER,
Lieut. U. S. N.

INDEX.

Page.

A.

- A-squadron, organization of, British manœuvres 29
- Aboukoff Gun Foundry torpedoes 430
- Accidents to machinery, frequency of, in naval manœuvres 60, 61
- Accidents to torpedo-boats in manœuvres 37, 64, 68, 74
- Accidents to vessels, frequency of, in naval manœuvres 36, 60, 61, 68
- Accumulators of large ships 190
- *Acevedo*, torpedo-boat, Spain 447–452
  - Boiler of 452
- Achill squadron, British manœuvres (*see* B-squadron).
- Actual pitch angle 208
- *Admiral* class of English ironclads 85, 88, 91, 95, 99, 100, 101, 110, 121
- *Admiral Lazareff*, battle ship, Russia, (Plate I) 81
- Admiralty, in relation to screw propulsion 211, 222, 235
- Admiralty regulations concerning use of forced draft 366, 369, 371
- Advisory board 294, 295, 296
  - Amount of steel tested by 296
- *Affondatore*, armored cruiser, Italy, (Plate I) 81
- *Agile*, torpedo-boat, France 437, 443
- Air discharge carriage for 14.4-foot torpedo, France 190
- Air-pressure, draft 366
- *Ajax*, *S. S.*, manœuvring power of 462
- *Alabama*, fight with *Kearsarge* 163, 178, 179, 180
- *Alarme*, torpedo-boat, France 437, 443
- Albini, Admiral:
  - Abstract of paper by 123
  - Designs for modern ships, (Plate X) 132
- *Alexander II*, battle ship, Russia, (Plate III) 81, 84
- *Alexandra*, battle ship, England, (Plate II) 81, 83
- Allan engine for dynamo of *Charleston* 289
- *Alma*, armored cruiser, France, (Plate I) 81
- *Alpha*, *S. S.*, screw trials of 205
- Alternative designs for first-class battle ships, England, (Plates V and VII) 87, 97, 118
- Alternative designs, disposition of armor and armament in first-class battle ships 99, 100, 101
- Aluminium bronze 219
- *Alvo*, *S. S.*, manœuvring power of 457, 462
- American Tube and Iron Company 324

Page.

- *Amiral Baudin*, battle ship, France, (Plate II) 81
  - Dimensions and speed of 117
  - Dynamo and engine, type and description of 288
  - Water-line protection of 107, 341
- *Amiral Duperré*, battle ship, France, bursting of 34^{cm} gun on board of 396
  - Water-line protection of 107
- Ammunition:
  - Delay in receiving on board, British manœuvres 32, 34, 39, 67
  - Kropatschek, '86 model 411
  - Lebel, '86 model 407
  - Mannlicher, '88 model 403–405
  - New English, '88 model 405
  - Remington 412
  - Secondary batteries 318, 398, 399
  - Supply of 1, 5, 7, 12, 13, 15, 17, 21
- Ampère meter 250, 290
- *Amphion*, cruise of, against commerce, British manœuvres 48, 54, 56
- *Amphitrite*, armored vessel, United States, price for armor 315
  - Electric installation of 246
- Analyses of steel by naval inspectors 306
- *Andromache*, cruiser, England 335
- Angle, pitch:
  - Actual 208
  - Of maximum effect 208
  - Virtual 208
- Angle, slip 208
- *Antelope*, torpedo vessel, England 335
- *Apollo*, cruiser, England 335
- *Aquila*, torpedo-boat, Italy 445
- Architects, Naval:
  - Institution of 199, 206, 210, 221, 225, 228, 229, 366
  - Transactions of 205
- Area:
  - Disk, of propeller 209
  - Of maximum efficiency 209
  - Of propeller blades 206, 209, 210, 211
  - Propelling 209, 211
- *Aretusa*, torpedo vessel, Italy 343
- *Ariete*, torpedo-boat, Spain 447–452
  - Accident to air-pump of 447
  - Accident to boiler of 447, 452
  - Speed of, under one boiler 452
  - Torpedo practice of 448
- Armament:
  - Auxiliary, in new battle-ship designs, England 101

Page.
Armament—Continued.
  Disposition of, on new battle ships 87, 88, 94–101
  Nature of heavy, on new battle ships 96, 101
Armington and Sims engine 247, 248, 249, 272, 289, 320
Arminius, armored vessel, Germany 83
Armor:
  Bethlehem, contracts for 310, 311, 315
  Cammell & Co., Sheffield, for United States 311
  Cammell, steel plate 424
  Compound 311
  Creusot 427
  Distribution of, on new battle ships, England 95
  Foreign, purchased by United States 293, 311
  Graphic history of distribution of 82
  Jessop, steel on steel armor plates 425
  John Brown & Co., Sheffield, for United States 311
  Light side, necessary for protection of crews 60
  Plates purchased abroad 311
  Protection and distribution, (Plates I, II, and III) 81, 82, 95, 96
  Protection for new barbette ship design, England 109, 110
  Protection for new turret ship design, England 103
  Schneider, for United States 311
  Tempering 427
  Trial of, for *Göta* 427
  Trials at Portsmouth, England 424–427
  Vertical compared with horizontal 129–131
  Vicker's steel plate 425
Armor-piercing projectiles (*see* projectiles).
Armored coast defense vessels, Germany 354
Armored cruisers:
  Russia 353
  Spain 355
  United States 329
Armored monitor, United States 330
Armored vessels:
  Chili 358
  Holland 360
Armstrong gun:
  Accident to 397
  Development of 6-in. B. L 136
  R. F 149
  Trials of 135
Army gun forgings:
  Contracts for 310, 316, 317, 376
  Test requirements for 377–380
Army guns submitted by private parties 381
Artillery exercises, torpedo-boats, Spain 449
Atlanta and *Weehawken*, contest of 163
Atlanta, cruiser, United States:
  Compared with *Constitution* 174
  Electric installation of 263
  Forged steel stem and stern posts for 298
  Powder for, purchased abroad 319
  Price paid for steel for 308
  Shafting for 296, 297
  Steel castings for 298
Attercliffe, "Specialty" Steel Works 225

Page.
Audacieux, torpedo boat, France 443
Augmented resistance 213
Australia, S. S., manganese-bronze screws of 221
Automatic engine governor 290
Automatic search-light 277
Automobile fish torpedo:
  Howell 430
  Schwartzkopff 428
  Whitehead 428
Auxiliary steam-engines and electric motors 279
Avant-garde, torpedo-boat, France 437, 443
Aventurier, torpedo-boat, France 437, 443
Avvoltoio, torpedo-boat, Italy 445
Azor, torpedo-boat, Spain, accident to machinery of 452

B.

B-squadron, British manœuvres 30, 31
Baldar, S. S., manœuvring power of 460
Ballarat, S. S., bronze *vs.* steel screw 220, 221
Baltimore, cruiser, United States 332
  Cast-steel stem and stern posts for 298
  Efficiency of dynamo of 273
  Electric installation of 246
  Electric light plant of 272
  Electric wiring of 265
  Steel shaftings for 297
  Test of dynamos for 273
Bantry Bay:
  Account of manœuvres at 40–49
  Plan of blockade of 46
Barbette, design for English battle ships 109
Barbettes *vs.* turrets 96, 109
Barcelo, torpedo-boat, Spain, winner of race 452
Barnaby, Sir N.:
  On "Protection of buoyancy and stability in ships" 120–122
  On screw propulsion 211, 212, 214, 216, 217, 234, 235, 237, 238, 239
Barnaby's "Marine Propellers" 200, 212, 224
Barracouta, cruiser, England 335
Barrosa, cruiser, England 335
Barrow battery, (Plate VIII) 86, 122
Base, advantages of, near blockaded port 62
Basic open-hearth steel 306, 307
Basilisk, cruiser, England 336
Batteries of new battle ships, England 96, 99, 102
Battery:
  Control of 169
  Firing by electricity 283
  Storage 282
Battle ships:
  Advantages of keeping in commission with reduced crews 10
  Details of suggested reduction of crews, France 9, 10
  England 334
  Germany 354
  Greece 360
  Italy 343
  Russia 352
  First-class, Admiral Albini, proposed, (Plate X) 132
  First-class, England, (Plates V and VIII) 98, 118, 334

Page.

Battle ships—Continued.
  Second-class, England 334
  Second-class, Admiral Albini, proposed, (Plate X) 132
Bayonet dimensions:
  Kropatschek, '86 model 411
  Lebel, '86 model 407
  Mannlicher, '88 model 404
  New English army, '88 model 405
Beagle, cruiser, England 336
Bearings, intermediate, shafting 228
B lair, S. S., manœuvring power of 462
Bellerophon, battle ship, England, screw trials 225, 227
Belliqueuse, experiments against, with melinite 420
Bellite 414
Belmes coal, speed trial with Spanish torpedo-boats with 452
Bennington, cruiser, United States 332
  Electric installation of 246
  Steel shafting for 297
Berehaven, defense of, British manœuvres .. 23, 37, 38
  Description of 37, 38
Beresford, Lord Charles, on duties of general staff 3
Berlin Machinery Construction Company, completion of two thousandth torpedo by 428
Bessemer steel plant, United States 294
Beta, S. S., screw trials of 205
Bethlehem Iron Works 297, 310, 311, 312, 316, 317, 323, 324
  Contracts with Navy and Army 311, 312, 315, 316, 317
  Establishment of, due to Navy . 310, 316, 317, 381
Bevis's feathering propeller 202
Biella, S. S., manœuvring powers of 463
Black Diamond Steel Works (Park Bros. & Co.) 312, 323, 324
Blade area 206, 209, 210, 211
Blades, Propeller 222, 223, 224
  Number of 210
  Shape of 210
Blitz, torpedo-vessel, Austria 357
Blockade:
  Breaking the, British manœuvres 24, 27, 46, 47, 48, 53
  Force necessary to maintain an effective . 62
  Operating the, British manœuvres .. 23, 24, 36, 37, 39, 40–46
  Raising the, British manœuvres 48
Boards:
  Fortification (*see* Fortification Boards).
  Gun Foundry (*see* Gun Foundry Boards).
  Naval Advisory (*see* Naval Advisory Boards).
  Steel (*see* Steel Boards).
Boiler:
  Compartments, arrangement of the *Lepanto's* 367
  Cowles' water tubulous 372
  Leading particulars of the *Lepanto's* 368
  Locomotive 366

Page.

Boiler—Continued.
  Oval, of the *Lepanto* 367
  Performance of the *Lepanto's* 366–369
  Special types of 366
  Thornycroft's water tubular 369–372
Boiler-room staff, necessity of efficient 365
Boom, construction of, at Berehaven 37
Booms, torpedo, difficulties with, in manœuvres 32, 36
Boss, propeller 223, 224
Boston, cruiser, United States:
  Electric installation of 263
  Prices paid for steel for 308
  Steel shafting of 297
  Stem and stern posts for 298
Bouet-Villaumez, torpedo-boat, France 443
Box:
  Deck stuffing 253, 254
  Junction 253, 254, 258
Boxes, regulator 250
Bracket, stern, propeller 228, 232
Bradford, R. B., Commander, U. S. N., Naval Inspector of Electric Lighting, remarks by 288
Brass plates, propeller blade 219
Brennan torpedo, England 428, 434
  Defense of the Isle of Wight with 434
  Expenditure for, in 1889–'90 434
  Testing station at Garrison Point 434
Brennus, battle ship, France 341
British Association, experiments in manœuvring merchant steamers 456
Britannia, S. S., Manganese-bronze screw .. 220
Bronze:
  Aluminium 219
  Manganese 218–223
  Phosphor 219
Brush Electric Company 263, 320
Buffalo, S. S., manœuvring experiments with 457, 458, 459, 462
Bulb angles for naval vessels 299

C.

Cail, Société, 35-metre torpedo-boats of .. 441, 442
Calliope, cruiser, England, escape due to screws of 220, 221, 222
Calypso, cruiser, England, manganese-bronze propellers of 222
  Cruise of against commerce, British manœuvres 53
Cambria Iron Works 297
Cammell & Co., armor supplied by 311
Cammell's steel armor plate 424
Canada, cruiser, England, gun mounts of .. 153
Canal, Suez, damage to screws in passage through 219, 228
Canet gun, trial of 386
Canet torpedo-gun 195, 196
Captain, cruiser, England, twin screws, trials of 225, 227
Care of ship-lighting plants 290
Caroline, cruiser, England, accident to gun of 397

Page.

Carpe, launch, triple screws of 229-232
Cartridge, fish torpedo, ejection 194
Carriages, gun (*see* Gun-carriage).
  Output of, at navy-yard, Washington 313
Cast-iron, as material for screw propellers 218, 219, 225
Cast-iron projectiles (*see* Projectiles).
Cast-steel, as material for screw propellers 219, 222, 223, 225
Cast-steel, projectiles (*see* Projectiles).
Castings, steel:
  Advantages over forgings 298
  Prices paid for, United States vessels 308
  Production of 294, 296, 298
  Stem and stern posts, table of 298
  Test requirements for 305
Castore, gun vessel, Italy 352
Casualties, gun (*see* Gun casualties).
Casualties, torpedo, Whitehead and Schwartzkopff 429
Casualties, torpedo-boat:
  Acevedo, Spain, boiler 452
  Ariete, Spain, boiler and air-pump 447
  Azor, Spain, machinery 452
  Halcon, Spain, torpedoes 448
  No. 102, France, loss 441
  No. 106, Italy, engine 446
  No. 110, France, loss 441
  Ordoñez, Spain, boiler 452
    torpedo 448
  Retamosa, Spain, screw 447
Catherine II, battle ship, Russia, gun mounts of 150
Cécille, cruiser, France 222, 342
Cellular water-line protection:
  Cellulose for 121
  Cocoanut fibre for 121
  Coke for 129
  Cork for 121
  India rubber for 121
  Woodite for 121
Cement, Portland, as covering for propeller blades 225
Centaur, cruiser, England 334
Centre of impact 169, 170, 171
Centurion, battle ship, 2d class, England 334
Ceram, S. S., trials of screws 210
Cerberus, torpedo-boat, Holland 445
Charleston, cruiser, United States 333
  Cast-steel stem and stern posts for 298
  Completion of battery of 376
  Dynamos of 271, 272
  Electric installation of 246
  Electric wiring of 265
  Steel shafting for 297
Chattahoochee, S. S., manœuvring power of 461
Chicago, cruiser, United States, electric installation of 263
  Prices paid for steel for 308
  Shafting for 297
  Steel castings for 298
  Stem and stern posts for, forged 298
Chester, S. S., manœuvring power of 461
Chilian armored vessel 358
Chiswick, propeller experiments at 202

Page.

Chrome Steel Company, Brooklyn, N. Y. 318
    projectiles 318
Circe, torpedo vessel, England 335
Circuit closer, Korn-Pichon 194
Circuit, temporary 286
  Underground 285
City of Alexandria, S. S., manœuvring power of 462
City of Augusta, S. S., manœuvring power of 457, 462
City of New York, S. S., manganese-bronze propellers of 221, 228
City of Paris, S. S., manganese-bronze propellers of 221
City of Puebla, S. S., manœuvring power of 462
City of Richmond, S. S., manœuvring power of 462
Claparède torpedo-boats:
  Bouet-Villaumez 443
  Edmond Fontaine 443
Clapp-Griffith steel plant, United States 294
Clapp-Griffith steel, employment of, in United States vessels 306
Clark's deflecting turrets 311
Closed stokeholds 366
Coal, Belmes, speed trials of Spanish torpedo-boats with 452
Coal and coaling, British manœuvres 58
Coal endurance of new battle ships, England 112
Coal supply, confusion of, at Milford Haven British manœuvres 36
Coaling ships at sea 24, 27, 36, 42, 58, 59
Coast-defense vessels:
  Germany 354
  No. 1, United States 331
Coast guard, England 33
Coast-guard ships, England 5, 28
Coefficient:
  Of frictional resistance 211
  Of normal pressure 208
  Of surface friction 208, 209
Coëtlogon, cruiser, France 342
Coils, steel, in English guns 137
Coke, for cellular water-line protection 129
Colliers, equipment of, to accompany squadrons 24, 36, 59
Colliers, small ones preferable 59
Collingwood, battle ship, England, (Plates III and VI) 81, 118
  Coal supply and endurance of 113
Colon, Cristóbal, cruiser, Spain 357
Colossus, battle ship, England, manganese-bronze screws of 222
Columbia, S. S., manœuvring power of 461
Commerce, attack upon and defense of, naval manœuvres 25, 50, 51, 53, 54, 56
Commonwealth, S. S., manœuvring experiments with 460
Commutator 258
Compartments, boiler, arrangement of the *Lepanto's* 367
Compasses:
  Location of, with respect to lighting plants 290

Page.

- Compasses—Continued.
  - Precautions necessary regarding 290, 291
  - Ships', as affected by electric plants 290
- Complements of ships, in first reserve:
  - England 5
  - France 8, 9
  - Germany 14, 15
- Compound armor 311
- Compressed steel, plant for production of, at Bethlehem 312
- *Concord*, cruiser, United States 332
  - Completion of battery of 376
  - Electric installation of 246
  - Steel shafting for 297
- *Conde de Venadito*, cruiser, Spain 356
- Conductors, electric:
  - Advantages of stranded 264
  - Flexible, for portable lights 265
- *Conqueror*, battle ship, England, (Plate II) 81
- *Constitution*, as compared with *Atlanta* 174
- Construction material, development and production of, for naval uses 293
- Construction of propellers 218
- Continental Iron Works 299, 324
- Contracts for armor and gun steel 294, 295, 311, 312, 315, 316, 317
- Contracts for torpedoes:
  - Howell, United States 430
  - Patrick, United States 434
  - Schwartzkopff, Italy 429
- Control of gun-fire 169-173
- Controllable torpedoes:
  - Brennan 434
  - Patrick 434
  - Sims-Edison 435
- Converter:
  - Edison 292
  - Swinburne's 292
- Copper plate, as preventive of screw corrosion 225
- *Cordelia*, cruiser, England, gun mounts of 153
- Cork for cellular water-line protection 121
- *Corona*, S. S., manœuvring experiments 458, 463
- Corrosion 225
- Corrugated furnaces 299, 324
- *Cosmao*, cruiser, France, manganese-bronze screws of 222
- Cost of English guns 383, 384
- Cost of forgings, castings, plates, shapes, and rivets 308
- Cost of gun-forgings and armor 311, 315, 316, 317
- *Coureur*, torpedo-boat, France 370
  - Boiler of 444
  - Coal consumption of 444
  - Speed, one boiler 444
- Cowles' water tubulous boiler 372
- *Cragside*, S. S., manœuvring power of 457, 461
- Cramp's Ship and Engine Building Company 322
- Crank-shafts, table of 297
- Cresilite 420
- Creusot, le, armor 311
  - armor, tempering 427
- *Cristóbal Colon*, cruiser, Spain 357
- Crucible steel 294, 306

Page.

- Cruisers, Admiral Albini's, (Plate X) 132
- Cruisers:
  - Armored, Spain 355
  - Armored, United States 329
  - Detached operations of, British manœuvres 25, 40, 53, 54, 55
  - England 334
  - English classification of, for manœuvres 25
  - France 341
  - Germany 354
  - Insufficiency of 61
  - Number needed to maintain blockade and protect commerce 62
  - United States—
    - First class 329
    - Third class 331
    - Nos. 7 and 8 329
    - Nos. 9, 10, and 11 330
    - *Vesuvius* type 331
- Cunard Line, manganese-bronze screws 221
- *Curtatone*, cruiser, Italy 344

D.

- *Dalton*, S. S., manœuvring power of 460
- *Dandolo*, battle ship, Italy 83
- *Daphne*, cruiser, England 338
- *Daphne*, launch, tubulous boilers of 372
- *Davout*, cruiser, France, dynamo and engine, type and description of 289
- De Bange system of obturation 137
- De Bange, 32-centimetre gun, trials of 395
- Deck stuffing-box 253, 254
- Defense against torpedoes, Admiral Albini upon 126
- Defense, hull, against torpedoes 84
- Defense-nets, torpedo, poor equipment of 32
- *Défi*, torpedo-boat, France 443
- Deflecting turret, Clark's 311
- Delaware Shipbuilding Company 322
- *Delfinen*, torpedo-boat, Denmark, boilers of 370
- Delta-metal 219
- *Denmark*, S. S., manœuvring power of 457, 461
- Designs for new battle ships, England 97
  - turret ship, (Plate V) 118
  - barbette ship, (Plate VII) 118
  - Table of particulars of 93
- *Destructor*, torpedo-boat, Spain 218
- Detonation of 80 pounds of gun-cotton between decks, (Plate IX) 86, 120
- *Devastation*, battle ship, England, (Plate II) 81, 84
  - Water-line, protection of 107
- Development in production of:
  - Armor 309
  - Castings, hull 298
  - Forgings 296, 312
  - Gun-carriages 150
  - Light plant, electric 319
  - Plates 299
  - Powder 319
  - Projectiles 318
  - Rapid-fire guns 149, 318
  - Secondary batteries 318
  - Shapes 299

Page.

- Development of the high-powered gun, 135
  - England, 135
  - France, 139
  - Germany, 143
  - United States, 146
- Development of the resources of the United States for the production of war material, 293
- Diameter, Propeller, 205, 209, 211
  - Ratio of pitch to, 206, 209, 230
  - Screw propeller, 205, 209, 211
- Direct current converter, 292
- Disability ratio, 210
- Disappearing carriages:
  - Naval, development of, 150
  - Pneumatic, land, development of, 151, 152
- Discharge:
  - Comparison of under-water with above-water, 197
  - Torpedo, 189–197
  - Torpedo, air, France, 190
  - Torpedo, gunpowder, Whitehead, 192
- Discussion on designs for battle ships, England, 94–96
- Disk area of propellers, 209
- Disposition of armament in recent battle ship designs, England, 94
- Distillers, double, 366
- Distribution of torpedo tubes:
  - Ships, 185
  - Torpedo-boats, 188
- *Dmitri Donskoi*, armored cruiser, Russia, (Plate III), 81
- *Dolphin*, United States dispatch-boat, electric installation of, 261
- Doxford, William, & Sons, liquid fuel torpedo boat, 440
- Draft, forced, Admiralty regulations concerning use of, 366
- Draft, natural, 366
- *Dreadnought*, battle ship, England:
  - Dimensions and speed of, 117
  - Water-line, protection of, 107
- Drifting torpedo, Pietruski, 436
- Driggs-Schroeder R. F. gun, 149, 398
  - Breech, mechanism of, 149, 398
  - Trial of, 398, 399
- Duels, naval, tactics in, 182
- *Duilio*, battle ship, Italy, (Plate II), 81
  - Water-line, protection of, 107
- Dundonald screw, 199, 201
- Duplex dynamo, 289, 292
- Dupont Powder Company, 319, 325
- *Dupuy-de-Lôme*, side-protected cruiser, France (Plate III), 81, 84, 233
- Dupuy-de-Lôme, naval constructor, France, 82
- Duquesne Steel Company, Pittsburgh, U. S, 297, 323
  - Shafting for *Petrel*, 297
- Dutch Indian navy, propeller trials, 210
- Duty of naval architect in designing ships, 106
- Duty of naval officers in designing ships, 106
- Dynamite guns:
  - Contract for, 382
  - Pneumatic, 382, 386–392
  - Purchase by Victorian government, 384

Page.

- Dynamite guns—Continued.
  - Record of firing tests of, 391, 392
  - Trial of, 386–392
- Dynamo:
  - Duplex, 289, 292
  - Edison's multipolar, 271
  - Gramme, 273
  - Room, location, arrangement, and ventilation of, on shipboard, 247, 270
  - Thomson-Houston, 320
  - Triplex, 289
  - United States naval, 271
  - United States naval, efficiency of, 273
  - Victoria, 275
- Dynamotor, 292

E.

- Eddy from screw, forming, 209
- *Edgar*, cruiser, England, 334
- Edison converter, 292
  - Electric Company, 246, 263, 264, 271, 273, 292, 320
  - multipolar dynamo, 247–249
  - torpedo motor, 283
- *Edmond Fontaine*, torpedo-boat, France, 443
- Effect of Government requirements in improving quality of steel, 296, 307
- Efficiency, maximum:
  - Area of, propeller, 209
  - Pitch angle of, 208
  - Slip angle of, 208
- Efficiency of naval dynamos, 273
- Efficiency, propeller, 199, 208, 209, 213, 217
- Efficiency under steam, British vessels in manœuvres, 60
- Effort, propulsive, 199, 209
- *Egyptian Monarch*, S. S., manœuvring power of, 460
- Electric conductors:
  - Installation of, 259
  - Tests of insulation of, 266
- Electric Engineers, Institution of, 290
- Electric installation of:
  - *Amphitrite*, coast-defense vessel, U. S, 246
  - *Atlanta*, cruiser, U. S, 263, 320
  - *Baltimore*, cruiser, U. S, 246, 320
  - *Bennington*, cruiser, U. S, 246
  - *Boston*, cruiser, U. S, 263
  - *Charleston*, cruiser, U. S, 246, 320
  - *Chicago*, cruiser, U. S, 263, 320
  - *Concord*, cruiser, U. S, 246
  - *Dolphin*, dispatch-vessel, U. S, 261
  - *Miantonomoh*, coast-defense vessel, U. S, 246
  - *Monadnock*, coast-defense vessel, U. S, 246
  - *New Hampshire*, receiving-ship, U. S, 262
  - *Omaha*, cruiser, U. S, 262
  - *Pensacola*, cruiser, U. S, 246
  - *Petrel*, cruiser, U. S, 246
  - *Philadelphia*, cruiser, U. S, 246
  - *Puritan*, coast-defense vessel, U. S, 246
  - *San Francisco*, cruiser, U. S, 246
  - *Terror*, coast-defense vessel, U. S, 246
  - *Vermont*, receiving ship, U. S, 246
  - *Vesuvius*, dynamite cruiser, U. S, 246
  - *Yorktown*, cruiser, U. S, 246, 265, 320

Page.

- Electric light, arrangement of, on shipboard, 252, 255
- Electric motors:
  - At shore stations, 286
  - On shipboard, 277
  - To replace auxiliary steam-engines, 280, 281
- Electric plants:
  - Attendants, 258
  - Care of, 257, 258
  - Of foreign ships, 273
  - Of new ships, 246, 271–273
- Electric search lights:
  - Equipment, torpedo-boats, 76
  - Purchased in France, 293, 320
- Electricity:
  - Firing batteries by, 283
  - For naval purposes, 283
  - Uses of, at shore stations, 270, 284
  - Uses of, in the Navy, 270
  - Uses of, on shipboard, 270
- *Elisabeth, Kaiserin*, cruiser, Austria, 357
- *Ellie*, steam-launch, New York, tubulous boiler of, 372
- Elliptical funnels, 367
- *El Paso*, S. S., manœuvring power of, 462
- Emergency trials, 365
- Emmens's torpedo howitzer, proposed, 382, 383
- Emmensite, 412, 413
- *Empong*, torpedo-boat, Holland, 445
- *Engine 31*, fire-boat, Boston, tubulous boiler of, 372
- Engineer, The (London), on the escape of the *Calliope* at Samoa, 220
- Engineering, (London), on hydraulic propulsion, torpedo-boats, 235
- Engineers, examination of, in England when assigned to ships, 7
- Errors in marksmanship, 164–167
- Estimates, torpedo, for 1889–'90:
  - England, 429
  - France, 429
- *Ethiopia*, S. S., manœuvring power of, 457, 458, 462
- *Etruria*, cruiser, Italy, 343
- *Eureka*, explosive propulsion vessel, 243
- Evaporators, steam, 366
- *Excelsior*, S. S., manœuvring power of, 457, 462
- Exercises, Spanish torpedo-boat:
  - Search lights, 448
  - Speed trial, 451
  - Torpedoes, 447
    - Artillery, 449
- *Exeter City*, S. S., manœuvring power of, 460
- Explosives, 412–418
  - Bellite, 414
  - Cresilite, 420
  - Emmensite, 412, 413
  - Melinite, 415

F.

- *Falco*, torpedo-boat, Italy, 445
- Fans for forced draft, 366
- *Fieramosca*, cruiser, Italy, 344
- Finished material, inspection made from, 302
- Finishing guns, capabilities of Washington plant for, 313

Page.

- Fire-boat *Engine 31*, Boston, tubulous boilers of, 372
- Firing batteries by electricity, 283
- Firmini projectiles, 158
- Fish-torpedo armament, 185
- Fish-torpedo cartridge, 190, 194
- Fixtures, electric light, 255–257
- *Flamingo*, torpedo-boat, Austria, 438
- *Flavio Gioja*, cruiser, Italy, boilers of, 367
- Fleet, formation for combat, 183, 184
- Fleischer's hydromotor, 240
- Flexible coupling, electric, for shipboard, 246
- Floor space for 100-ampère generating set, 248
- Floor space for 200-ampère generating set, 248
- *Flores*, gun-boat, Dutch Indian navy, propeller, experiments with, 210
- Flotilla, Spanish, torpedo-boat exercises, 447
- *Foca*, torpedo-boat, Holland, 445
- *Forbin*, cruiser, France, 222, 343
- Forced draft, admiralty regulations concerning, 366
- Foreign electric-light plants for ships, 273
- Forged steel (*see* Forgings).
- Foundation for 200-ampère plant, 249
- Forged-steel projectiles (*see* Projectiles).
- Forgings:
  - Contracts for, 296, 297, 311, 316, 317
  - Gun, Army, 376
  - Gun, Army, test requirements for, 376–380
  - Prices paid for, 308, 311, 316, 317
  - Production of, 293, 296, 297, 312
- *Formidabile*, battle ship, Italy, (Plate I), 81, 82
- *Formidable*, battle ship, France, 341, 342
- Fortification Board, 309
- *Franz Josef*, battle ship, Austria, 357
- Freeboard, high, preferred in new battle ships, England, 96
- Friction, propeller, 211, 222, 225
- Friction, surface, propeller, 209, 211, 212
  - Coefficient of, 208, 209
- Frictional resistance, coefficient of, 211
- *Friedland*, battle ship, France, (Plate I), 81
- Funnels, elliptical, 367
- *Furiex*, armored vessel, France, (Plate II), 81, 84
- Fuze for gun-cotton, von Förster, 161

G.

- *Gamma*, S. S., screw experiments, 205, 206
- Gatewood, naval constructor, U. S. N., report of Naval Advisory Board, 294
- Gauge, vacuum or back pressure, 250
- *Gaulker*, torpedo-boat, Austria, 438
- *General Admiral*, armored cruiser, Russia, (Plate II), 81
- General Staff, Naval (*see* Naval General Staff).
- Germania Works torpedo-boats, Turkey, 452
- *Ghang-oot*, battle ship, Russia, 353
- Gironde, Société de la:
  - 34^m boats of, 443
  - 35^m boats of, 441
- *Gleaner*, torpedo-boat, England, 335
- *Gloire*, armored vessel, France, (Plate I), 81, 82

Page.

- *Goentor*, torpedo-boat, Holland 445
- *Goldfinch*, gun-vessel, England 336
- *Gossamer*, torpedo-vessel, England 335
- *Göta*, battle ship, Sweden, trial of armor for 427
- *Goubet*, submarine torpedo-boat 454
- Graphic History of Armor Protection and Distribution, (Plate I, II, III) 81, 82
- Graydon dynamite shell 159
- Great Eastern Railway steamers, twin screws of 229
- *Grenade*, armored gun vessel, France 342
- Grenfell sights 385
- Griffith screw propeller 200, 210
- *Grosidstchi*, gun vessel, Russia 353
- Ground detector 250, 251
- Gruson R. F. Gun 400
- Guide-blade propeller, Thornycroft's 203
- Gun-boats, Spain 356
- Gun-captains, requirements for 168
- Gun-carriages 150–154, 313, 324
  - Bureau of Ordnance design 153, 154
  - Land 151, 152
  - Naval disappearing 150
  - Pneumatic 151, 394, 395
  - Vavasseur 152, 153
  - 6-inch R. F., United States 153, 154
- Gun casualties 396, 397
  - Accident to Armstrong gun 397
  - Accident to *Caroline's* gun 397
  - Accident to 42^{cm} gun 141
  - Accident to *Iphigénie's* gun 397
  - Bursting of *Duperré's* 34^{cm} gun 396
  - Disabling of *Impérieuse's* guns 397
  - Disabling of 9.2-inch B. L. gun 138
  - Disabling of 10.4-inch B. L. gun 138
- Gun-cotton shell 160, 375, 420–423
- Gun fire:
  - Accuracy of 164–169
  - Control of 169–173
- Gun forgings:
  - Appropriations for 376
  - Army, submitted by private firms 381
  - Army, test requirements for 376–380
  - Contract for .. 311, 312, 314, 315, 316, 317, 318, 376, 381
  - Purchase of, abroad 293, 311, 316, 317
  - Specifications governing 376–380
- Gun Foundry Board 309, 310
- Gun-metal for propellers 218, 221, 222
- Gunpowder discharge, ships, France 192
- Gunpowder discharge, torpedo-boats, France 188, 189, 196
- Gun-shields, plates for 312
- Gun steel, Bethlehem contracts for . 311, 312, 315–317
- Gun tactics (*see* Tactics, gun).
- Gun, torpedo, Russia 188, 190
- Gun trials 135, 136, 149, 386–393, 395, 398, 399
  - Armstrong gun 135, 136
  - Driggs-Schroeder gun 149
  - Pittsburgh gun 393
  - Pneumatic dynamite gun 386–392
  - Thurlow gun 393
- Gunnery, Naval 163

Page.

- Guns:
  - Armstrong 135, 397
  - Army, submitted by private parties 381
  - Capabilities of assembling and finishing, Washington navy-yard 313
  - Dynamite (*see* Dynamite guns).
  - English:
    - Construction of 135–137
    - Cost of 383, 384
    - Delays in furnishing 384
    - Liners of 67-ton 138
    - Number completed during past year 384
    - Steel coils in 137
    - Supplied by War Department 383, 384
    - Table of 139, 148
    - Wire-wound 138
    - Woolwich and Armstrong, compared with Krupp 143, 144
    - 16.25-inch B. L 138
    - 13.5-inch B. L 138
    - 12-inch B. L 136, 138
    - 6-inch B. L 139
  - French:
    - 1870 model, table of 139
    - 1875 model 140
    - 1881–'82 model 141
    - 1884 model 142
    - 34^{cm} features of 140, 142
    - 32^{cm} 142
    - 240^{mm} De Bange 142
    - 42^{cm} accident to 141
    - Canet 386
    - Tables of 142, 148
  - German (*see* Krupp).
  - High-Power, development of the 135
  - Krupp:
    - 40^{cm} 143, 144, 145
    - 35.5^{cm} 144
    - 30.5^{cm} 144
    - 28^{cm} 144
    - 26^{cm} 145
    - 24^{cm} 145
    - 15^{cm} 145
    - Table of 145
  - Machine, tactics of 180
  - Rapid-fire:
    - Armstrong 149
    - Driggs-Schroeder 149, 398, 399
    - Gruson 399–401
    - Hotchkiss 149
    - Maxim 401, 402
    - Nordenfelt 149, 401, 402
  - United States 146
    - Driggs-Schroeder 149, 398, 399
    - Dynamite (*see* Dynamite guns).
    - Modern, for Naval Academy 376
    - Modern, for Training Squadron 376
    - Tables of 146, 148
  - Wire-wound:
    - English, opinions of Court on 137
    - Maitland 9.2-inch 138
    - Russian 385
- *Gutheil*, S. S., manœuvring power of 460
- *Guyandotte*, S. S., manœuvring power of .. 459, 462

Page.

- *Gymnote*, submarine boat, France 438, 453
  - Storage batteries of 282

H.

- *Habana*, torpedo-boat, Spain 447
  - Rupture of crown sheet 447
- *Habang*, torpedo-boat, Holland 445
- *Halcon*, torpedo-boat, Spain 447–452
- Hammer, heavy, at Bethlehem 312
- Hammered steel propeller blades 224
- Hanna, Donald & Wilson torpedo-boat, England, colonial 441
- Harlan & Hollingsworth Company, United States 322
- *Harpie*, torpedo-boat, Austria 438
- *Havemeyer, Wm. F.*, fire-boat, New York, tubulous boiler of 372
- Haslar, experimental station at 110, 118
- *Havhesten*, torpedo-boat, Denmark, tubulous boilers of 369
- *Hawke*, cruiser, England 334
- Heats, inspection of material by 295, 302
- *Hebe*, torpedo-boat, England 335
- Hengst powder 417
- *Hercules*, battle-ship, England, (Plate I) 81, 225, 227
  - Water-line protection of 107
- Herreshoff Manufacturing Company 322
- High explosive projectiles 159–162, 418–423
  - Effect upon the distribution of armor 177
- High explosives, sources of supply of 319, 325
- Hill Line Steam-ships, twin screws 229
- Hirsch screw 200
- *Hoche*, battle ship, France, (Plate I) 81, 84, 341
- Homestead Iron Works 323
- Hollow shaft bearing, propeller 228
- Holzer projectiles 158
- *Hood*, battle ship, England 334
- Hoopes & Townsend 323
- Hoops for guns, contracts for 316, 317
- Hotchkiss Ordnance Company, United States plant 318, 325, 375
  - R. F. guns 149
  - manufacture of torpedoes by 319, 430
  - 3-pounder, accuracy of 168
- Howell torpedo:
  - Contract with Navy Department 319, 430
  - Place of manufacture 319
- Howitzers, Emmens torpedo, proposed breech-loading 382
- Hub, propeller 223
- Hull, defense of against torpedoes 84
- *Hydra*, battle-ship, Greece 360
- Hydromotor:
  - Fleischer's 240–242
  - Maginot's 242

I.

- I-beam, 24-inch, rolled at Homestead 299
- *Illinois*, S. S., manœuvring power of 463
- Immersion of propeller 216
- *Imperator Nicolai I*, battle ship, Russia 353
- *Impérieuse*, armored cruiser, England, (Plate III) 81, 85
  - Disablement of guns of 397
  - Disposition of armament of 88, 100

Page.

- Improvement in quality of steel, United States 296, 300, 313
- Incandescent electric light:
  - Installations of past year for United States ships 245
  - Plants, United States ships 319, 320
- Inclined shaft, propeller 214–216
- Incombustible fitting, electric, introduction of 255
- Increased facilities for the manufacture of plates and shapes 299
- Increase in test requirements, and improvement in quality of steel 300, 313
- *Independencia*, cruiser, England, screw experiments with 225, 227
- Indian Navy, Dutch, screw trials 210
- India-rubber and Gutta-percha Insulating Company 264
- India-rubber:
  - For cellular water-line protection 121
  - For insulating purposes 260
- *Indomptable*, battle ship, France, (Plate II) 81
  - Dynamo and engine, type and description of 288
- *Inflexible*, battle ship, England, (Plate II) 81
  - Dimensions and speed of 117
  - Water-line protection of 107
- Inman line, manganese-bronze propellers of 221
- Inspection of—
  - Electric lighting, office of 320
  - Steel by naval officers 295, 296
  - Steel, commenced 295
- Inspector, Admiralty, test of manganese-bronze before 222
- Institution of Electrical Engineers 290
- Institution of Naval Architects 206, 210, 221, 225, 228, 229, 366
- Institution of Naval Architects, transactions of 205, 206
- Institution, United Service 369
- Instructions to Steel Inspectors, extracts from 302–305
- Insulation—
  - Of electric wires 259
  - Tests 266–268
- Intermediate bearings, shafting 228
- *Invincible*, battle ship, England, screw trials of 225, 226
- *Iphigénie*, battle ship, France, accident to gun of 397
- *Irene*, dispatch vessel, Germany 355
- *Iris*, cruise against commerce, British manœuvres 51
  - Screw trials 205, 212, 228
- Iron, cast, for propellers 218, 219, 225
- *Iron Duke*, battle ship, England, screw trials 225, 226
- Isherwood, experiments on screw propulsion 210, 215, 216
- *Italia*, battle ship, Italy, (Plate II) 81, 83, 345
  - Dimensions and speed of 117
  - Water-line protection of 107
- *Itsukusima*, armored coast defense vessel, Japan 361

Page.

J.

- Jackets for guns, contracts for 316, 317
- *Jagd*, dispatch-vessel, Germany 355
- *Jerome*, S. S., manœuvring power of 462
- Jessop steel on steel armor plate 425
- Johnson, I. G., & Co 318, 325
- Junction box, electric 253, 254, 258

K.

- *Kaiserin Elisabeth*, cruiser, Austria 357
- *Kearsarge-Alabama* gun tactics 163, 178–180
- Kennedy, Professor, experiments, tubulous boiler 371
- Keys for propellers 224
- *Komet*, torpedo-vessel, Austria 357
- *Korniloff, Admiral*, cruiser, Russia, manganese-bronze screws of 222
- Korn-Pichon, circuit closer 194
- *Krähe*, torpedo-boat, Austria 438
- Krantz, Admiral, minister of marine, France 370
- Kropatschek, magazine rifle, Portugal 411
- Krupp, contracts for shafting for United States ships 297
- Krupp guns:
  - 40^{cm} 143, 144, 145
  - 35.5^{cm} 144
  - 30.5^{cm} 143, 144
  - 28^{cm} 144
  - 26^{cm} 145
  - 24^{cm} 145
  - 15^{cm} 145
  - Table of 145
- Krupp projectiles 157, 158
- *Kukuk*, torpedo-boat, Austria 438

L.

- *La Bretagne*, S. S., manœuvring power of .. 462
- *La Champagne*, S. S., manœuvring power of 462
- *Lahn*, S. S., quick passage of, with bronze propeller 222
- *Lake Huron*, S. S., manœuvring power of .. 457, 462
- *Lalande*, cruiser, France 342
- Lamps, electric, used on shipboard 255, 257
- Landing party, special, organized in English ships 36, 37
- *Lapwing*, gun vessel, England 336
- *Lazareff, Admiral*, cruiser, Russia, (Plate I) . 81
- Lebel powder 417
- Lebel repeating rifle 407–410
- *Leda*, torpedo vessel, England 335
- *Léger*, torpedo vessel, France 341
- *Lepanto*, battle ship, Italy 83, 344
  - Dimensions and speed of 117
  - Locomotive boilers of 366–368
  - Water-line protection of 107
- *Lévrier*, torpedo vessel, France 341
- Lighting plants for shore stations 284, 291
- Lights, search 275–277
- *Liguria*, cruiser, Italy 343
- Linden Steel Company, Pittsburgh 323, 324
- Liverpool, capture of, British manœuvres .. 52, 63
- *Llandaff*, S. S., manœuvring power of 460
- Location of dynamo room relative to compasses 270
- Locomotive boilers, *Lepanto's* 366–369
- Log, engineer's, *Zealandia*, S. S 223
- Loire, Societé de la 441–443
  - *Alarme*, torpedo boat, France 443
  - *Aventurier*, torpedo-boat, France 443
  - *Défi*, torpedo-boat, France 443
  - *Ouragan*, torpedo-boat, France 443
  - *Téméraire*, torpedo-boat, France 443
  - 34^{m} torpedo-boat, France 443
  - 35^{m} torpedo-boat, France 441
- *Lombardia*, cruiser, Italy 343
- London Engineer, The, on the escape of *Calliope* at Samoa 220
- London Engineering, on hydraulic propulsion, torpedo-boats 235
- Lough Swilly, manœuvres at 41–48
- Lyddite 161

M.

- Machine guns 398
- Machinery notes 362
- *Magenta*, armored vessel, France, water-line protection of 107, 341
- *Magicienne*, cruiser, England 337
- Maginot's hydromotor 242
- *Magpie*, gun-vessel, England 340
- Main-deck plates (*see* Plates, main deck).
- *Maine*, armored crusier, United States 332
  - Armor for 311
  - Basic open-hearth steel for 306, 307
  - Machinery for 332
  - Price of steel for 308
  - Steel shafting for 297
- Maitland, Colonel, advocacy of steel for guns 136, 137
- *Majestic*, S. S., arrangement of screws of 229
- Manchester, Sheffield and Lincolnshire Railway, twin-screw boats of 229
- Manganese-bronze for propellers 218–223
- Manganese-Bronze and Brass Company 219
- Mangin projector 292, 320
- Mangin's screw propeller 201
- *Manhattan*, S. S., manœuvring power of .. 456, 459, 460
- Mannlicher magazine rifle, adopted by:
  - Austria 403
  - Belgium 405
  - Germany 410
- Manœuvres, naval (*see* Naval manœuvres).
- Manœuvring power of ocean steamers 456
- Manuel, Mr. G. W., remarks on propellers . 219, 221
- Manufacture of armor and gun-steel for Government by private firms 312, 315–317
- *Marabu*, torpedo-boat, Austria 438
- *Marathon*, cruiser, England 337
- *Marceau*, battle ship, France, (Plate III) . 81, 84, 341
- Marchal, M., on screw propulsion 229–232
- *Marcia*, S. S., manœuvring power of 461
- *Marco Polo*, cruiser, Italy 343
- *Maria Pia*, battle ship, Italy, (Plate I) 81
- Marine Engineer, The, on Fleischer's hydromotor 240
- "Marine Propellers," Barnaby's 200, 212, 224

Page.
Marksmanship:
  Errors in ... 164–167
  Qualifications for ... 168
  Relative efficiency in, with high and low pressure guns ... 167
  With great guns ... 164
Material for propellers ... 218
Materials unsuccessfully tried for insulating on shipboard ... 259
Maudslay, Sons & Field, Messrs., screw experiments by ... 222
Maxim powder ... 417
Maxim R. F. guns ... 401, 402
Maximum efficiency:
  Pitch angle of ... 208
  Slip angle of ... 208
Mayflower, training brig, England ... 335
Medea, cruiser, England ... 337
Méditerranée, Société de la ... 441–443, 446
  Agile, torpedo-boat, France ... 443
  Audacieux, torpedo-boat, France ... 443
  Maluca, torpedo-boat, Roumania ... 446
  Sborul, torpedo-boat, Roumania ... 446
  Sineul, torpedo-boat, Roumania ... 446
  35^{m} torpedo-boat, France ... 441
  No. 102, torpedo-boat, France ... 441
  No. 110, torpedo-boat, France ... 441
Nedusa, cruiser, England ... 337
Melinite ... 160, 415
Melinite shell ... 160, 375, 419
Melita, cruiser, England ... 339
Melpomene, cruiser, England ... 337
Men, enlisted, prizes to ... 376
Menard-Dorian, criticism of French scheme of mobilization ... 9, 10
Mersey, distribution of torpedo-tubes, England ... 186
  Hollow steel shaft ... 228
  Underwater tubes of ... 186, 197
Metal:
  Delta, for screw propellers ... 219
  Gun, for screw propellers ... 218, 221–223
Meter:
  Ampère ... 250, 290
  Volt ... 250, 290
Mexico, S. S., manœuvring power of ... 457, 461
Miantonomoh, coast defense vessel, U. S., armor for turrets of ... 311
  Electric installation of ... 246
  Steel for turrets of, purchased abroad ... 311
Midvale chrome steel for projectiles ... 318
    gun forgings ... 312–314
    production of steel shafting at ... 297
    steel Company ... 297, 311–318, 323, 324
    steel for rapid-fire guns ... 318
Mild steel for propellers ... 218, 219, 221
Minneola, S. S., manœuvring power of ... 463
Minerva, torpedo vessel, Italy ... 343
Minotaur, battle ship, England, (Plate I) ... 81
  Dimensions and speed of ... 117
Miranda, S. S., manœuvring power of ... 460
Mobilization, naval ... 1
  A test of the state of preparation ... 4
  At Toulon, points to be determined ... 11, 64, 65, 66

Page.
Mobilization—Continued.
  Comments on different systems of preparations for ... 20
  Considerations affecting preparations for ... 2
  Criticisms of—
    English ... 20
    French ... 20
    German ... 20
    Italian ... 20
  Definition of and classification of subjects under ... 4
  In connection with a naval general staff 3, 4
  Of harbor defenses and supply at Spezia 70
  Organization for and scope of ... 1
  Preparations for, in—
    Austria ... 17
    England ... 5
    France ... 8
    Germany ... 12
    Italy ... 18
  Suggestions for a complete system of preparations for, for the United States 20
  Tests in—
    France ... 11
    Germany ... 16, 17
Molding, sectional ... 252
Monadnock, coast defense vessel, U. S., corrugated furnaces of ... 300
  Electric installation of ... 246
  Shafting of ... 297
Monarch, battle ship, England, screw trial of, (Plate I) ... 81, 225, 227
Monitor, tactical features of the ... 178
Monitors, prices paid for armor for ... 311, 315
Montebello, torpedo-vessel, Italy ... 352
  Triple screws of ... 232
Monzambano, torpedo-cruiser, Italy, triple screws of ... 232
Morgan Iron Works ... 297
Mortar, French 24^{cm} steel, for sea service ... 386
Motor, torpedo, Edison ... 283
Motors, electric ... 277
  At shore stations ... 286
  On board ship ... 277–281
  To replace auxiliary steam-engines ... 280, 281
Multiple screws ... 225

N.

Naluca, torpedo-boat, Roumania ... 446
Narhvalen, torpedo-boat, Denmark, boilers of ... 369, 439
Nashua Steel and Iron Company ... 323
National defenses, development of, by Navy 310
Natural draft ... 366
Nautilus, launch, hydraulic propulsion, France ... 234, 242
Naval Academy, modern guns for ... 376
Naval Advisory Board ... 294, 295, 296
  Steel tested by ... 296
Naval Architects, Institution of:
  On propulsion ... 199, 206, 210, 221, 225, 228, 229
  Transactions of ... 205

Page.

- Naval brigade:
  - Operations of, U. S. Atlantic squadron, Camp Osceola 77
  - Organization and camp routine 78
- Naval Dynamos 271
  - Efficiency of 273
- Naval General Staff:
  - Duties of 3, 4
  - Importance of 3
  - Its duties distinct from those of construction and design 3
- Naval gunnery 163
- Naval manœuvres:
  - England, account of 23–57
    - Advantages of base near by 62
    - Comments upon the 57
    - Coal and coaling 58
    - Force necessary to maintain a blockade 62
    - Maps of 62
    - Mobilization 32, 33
    - Scheme and rule 23
    - Signals and communications 59
    - Steaming efficiency and endurance 60
    - Strategy of 62
    - Value of torpedo-boats to blockaders and blockaded 57, 58
  - France, account of 63–68
    - Attack upon the coast of Algeria 63
    - August and September manœuvres 64
    - Blockade of Ajaccio 63, 64
    - Comments upon the 68, 69
    - Degree of preparation of ships at 66
    - Escape of the *Redoubtable* 64
    - Failure of torpedo attack 65, 66
    - June manœuvres 63
    - Maps of 80
    - Object of manœuvres in August and September 64
    - Organization of squadrons participating in 68
    - Scheme of operation in August and September 64
    - Squadron evolutions, August 20 to 25 65
    - Torpedo attack upon Toulon 64
  - Italy, account of 69–73
    - Attack upon Genoa 70, 72
    - Attack upon islands of Tuscan Archipelago 70, 71, 72
    - Attack upon Spezia 71, 72
    - Comments upon the 73
    - Maps of 80
    - Objects of attack and defense 69
    - Scheme of attack and defense, first period 70
    - Scheme of attack and defense, second period 71
    - War problems proposed 69
  - Spanish torpedo-boat, account of 74–77
    - Maps of 80
    - Program of 75
- Naval mobilization (*see* Mobilization, Naval)
- Naval officers as steel inspectors 295

Page.

- Naval operations, United States 77–80
- Navy:
  - Contracts for gun forgings 316, 317
  - Scientific papers 205
- Navy-Yard:
  - Mare Island, California 322
  - Norfolk, Va 322
  - Washington, D. C 309, 310, 318, 324, 325
- *Neptune*, battle ship, France 341
- Nets, torpedo, England 436
  - Difficulties in handling 32
- *Newark*, cruiser, United States 332
  - Price paid for steel for 308
  - Steel cast stem and stern posts of 298
  - Steel shafting for 297, 308
- New English army magazine rifle 405
- *New Hampshire*, electric installation of 262
- *New Ironsides*, armored vessel, United States 83
- *Nicolai I, Imperator*, battle ship, Russia 353
- *Nibbio*, torpedo-boat, Italy 445
- *Nile*, battle ship, England, (Plate IV) 95, 99, 101, 118
- Nordenfelt R. F. guns 149, 401, 402
- Normal pressure, coefficient of 208
- Normand torpedo-boats 442, 443, 451
  - *Avant-garde*, torpedo-boat, France 443
  - *Barcelo*, torpedo-boat, Spain 447–452
  - *Nos.* 126, 127, 128, 129, torpedo-boats, France 444
  - 34-metre torpedo-boats, France 443
- North German Lloyd S. S., maganese-bronze screws of 222
- Norway Steel and Iron Company 323
- Notes:
  - Armor 424
  - Machinery 362
  - Of discussion on designs for English battle ship 94
  - Manœuvring power of ocean steamers 456
  - Ordnance 375
  - Ships 327
  - Torpedoes 428
  - Torpedo-boats 437
- *Nueces*, S. S., manœuvring power of 461
- Number of blades, propeller 210
- *Nymphe*, cruiser, England 338

O.

- *Ocean*, battle ship, France, (Plate I) 81, 84
- Offices and quarters, lighting at shore stations 285
- Officers, Engineer, efficiency of, needed 365
- *Old Dominion*, S. S., manœuvring power of 461
- Oliver Bros. & Phillips 323
- *Omaha*, cruiser, United States, electric installation of 262
- Open-hearth steel 294, 306, 307
  - Basic 306, 307
  - Employment of, in the United States vessels 306
  - Plant, United States 294
- Open stokeholds 366
- Operations of A and B squadrons, British manœuvres 49–53

Page.

- Operations of detached cruisers, British manœuvres 53–57
- Opposition to Government system of steel inspection 295, 296
- Orders, secret, to Achill Admirals, Brit. manœuvres 46
- Ordnance notes 375
- Ordnance and armor, developement and production of 309
- Ordnance committee, English 136, 137
- *Ordoñez*, torpedo-boat, Spain 447–452
- *Oregon*, S. S., manœuvring power of 460
- *Orizaba*, S. S., manganese-bronze propellers of 222
- *Oroya*, S. S., manganese-bronze propellers of 222
- Otis Rolling-mill 299
- *Ouragan*, torpedo-boat, France 443
- Outside lighting at naval shore stations 284
- Oval boilers of the *Lepanto* 367

P.

- Pacific and Orient Steam Navigation Company steamers, manganese-bronze propellers of 222
- Pacific coast, ships built on 293, 321, 322
- Pacific Rolling-mills 298, 323, 324
- *Palestro*, armored vessel, Italy, (Plate I) 81
- *Pallas*, cruiser, England 335
- *Pandora*, cruiser, England 335
- Papers, Navy Scientific 205
- Parà rubber, stipulated for in naval contracts 260
- Park Bros. & Co. (Black Diamond Steel Works) 299, 323, 324, 376
- *Partenope*, torpedo vessel, Italy 343
- *Partridge*, gun vessel, England 339
- Patrick torpedoes:
  - American model of 434
  - Experiments at Brest with 434
  - Projected defense of Brest with 434
  - Finding and recommendation of U. S. Naval Board upon 435
  - French model of 434
  - Order by United States of, conditions 435
- *Peace*, missionary boat, Congo, tubulous boilers of 369
- *Peacock*, gun vessel, England 339
- *Pearl*, cruiser, England 335
- *Peconic*, S. S., manœuvring power of 460
- *Pedro*, S. S., manœuvring power of 462
- *Pelayo*, battle ship, Spain 356
  - 28^{cm} guns, trial of 395
- *Pelorus*, cruiser, England 335
- Penetration, Lebel magazine rifle, peculiarities of 410
- Peninsular and Oriental Steam Navigation Company steamers, manganese-bronze screws of 221
- Pennsylvania Steel Company 323
- *Pennsylvania*, S. S., manœuvring power of 461
- *Pensacola*, cruiser, United States:
  - Electric installation of 246
  - Electric plant of 271
  - Electric wiring of 265
- *Peral*, submarine boat, Spain 438, 454

Page.

- *Persian*, cruiser, England 335
- *Petrel*, cruiser, United States 332
  - Completion of battery of 376
  - Electric installation of 246
  - Steel shafting for 297
- Petroleum for explosive propulsion 243
- *Petropaulovsk*, armored vessel, Russia, (Plate I) 81, 83
- *Petr Veliki*, battle-ship, Russia, (Plate II) 81, 84
- *Pheasant*, gun vessel, England 339
- *Philadelphia*, cruiser, United States 332
  - Cast-steel stem and stern posts for 298
  - Electric installation of 246
  - Steel shaftings for 297
- *Philomel*, cruiser, England 335
- *Phœbe*, cruiser, England 335
- *Phœnix*, cruiser, England 335
- Phœnix Iron Company 323
- Phosphor-bronze 219
- Phosphorus limit, Government steel 302, 303, 304, 305, 306
- Picric acid and the picrates 413
- *Piemonte*, cruiser, Italy 348–352
  - Power of battery of 175, 176
- Pietruski drifting torpedo 436
- *Pigeon*, gun vessel, England 339
- *Pigmy*, gun vessel, England 339
- Pitch, propeller 206, 208, 209, 214, 215, 222
- Pitch angle 208
  - Actual 208
  - Virtual 208
- Pitch, ratio of, to diameter 230
- Pitching, effect of, on propeller 217
- Pitchometer 223
- Pitting 225
- Pittsburgh cast-steel gun 393
- Pittsburgh Steel Casting Company 323, 324
- *Planet*, torpedo vessel, Austria 358
- Plant:
  - Care of ship-lighting 290
  - Steel-producing, table of 294
- Plants:
  - Electric, of *Baltimore*, *Charleston*, *Pensacola*, and *Yorktown* 271–273
  - Foreign, electric, for ships 273
  - Lighting, for shore stations 284–287
- Plates:
  - Copper, for propeller blades 225
  - Boiler 295, 304, 306
  - Hull 295, 302, 306
  - Prices paid for 308
  - Protective-deck 303, 306
  - Sources of supply of 323, 324
- *Plover*, gun vessel, England 339
- Pneumatic dynamite gun:
  - Trial of 386–392
  - Carriage, trial of 394, 395
- Pneumatic dynamite guns:
  - Contract for 382
  - Purchase by Victorian Government 384
- *Pole Star*, imperial yacht, Russia 353
- *Polluce*, gun vessel, Italy 352
- *Polyphemus*, torpedo-vessel, protected, England 186, 188, 197, 367
  - Underwater torpedo tubes of 186, 188, 197

Page.

- *Pontiac*, S. S., manœuvring power of 462
- *Popoffkas*, circular armor-clads, Russia 233
- Portables for holds, double bottoms, etc 256, 257
- *Portia*, S. S., manœuvring power of 461
- Portland cement 225
- Portsmouth armor trials 424–426
- Position, screw 212
- Pottsville Iron and Steel Company 323
- Powder:
  - German—
    - Brown and black, table of comparisons of 155
    - Deliquescence of 157
    - Rhenish-Westphalian 156
      - P. P. C/82 156
      - P. P. C/86 156, 416
      - Analysis of charcoal of 156
      - Comparative tests of new and old 415, 416
    - Rottweil-Hamburg 155
      - Analysis of 155
      - C/75 155
      - C/82 155, 156
    - Prismatic 154, 155
  - Hengst's 417
  - Lebel 417
  - Manufacture in United States 319, 325
  - Maxim 417
  - New French 157
  - Purchased in Germany 293, 319
  - Sévran-Livry 157
  - Slow-burning 155
  - Smokeless 155
- Power:
  - Maximum with forced draft 366
  - Natural draft 366
- Practice vessel, United States 330
- Pratt & Whitney Company 318, 324, 375
  - Plant 375
- Presentment angle 174
- Pressure:
  - Air for draft 366
  - Normal, coefficient of 208
- Prices paid for:
  - Armor and gun steel 311, 316, 317
  - Rivets, plates, shapes, castings, and shafting 308
- *Prinzess Wilhelm*, cruiser, Germany 355
- Prismatic powder 154, 155
- Prizes to enlisted men 376
- Projectiles:
  - Armor-piercing 157, 158, 318, 319
  - Cast-iron 318, 325
  - Cast-steel 159, 318, 325
  - Chilled cast-iron 157
  - Firmini 158
  - Forged steel 157, 158
  - Holzer 158
  - Krupp 157, 158
  - Shrapnel (*see* Shrapnel).
  - St. Chamond 158
  - Table of trials of 158
- Projectiles, high explosive:
  - Graydon 159
  - Gun-cotton 160

Page.

- Projectiles, high explosive—Continued.
  - Melinite 160
  - Smolianinoff 160
  - Snyder 160
- Propeller blade 222, 223, 224
  - Area of 206, 209, 210, 211
  - Brass sheathing for 219
  - Method of making, torpedo-boat 224
  - Number of 210
  - Shape of 210, 211
  - Material best suited for 218–225
- Propeller guard, torpedo-boat, Thornycroft 439
- Propeller, screw, the 199
  - Boss 223, 224
  - Construction 218
  - Diameter 205, 209, 211
  - Efficiency 199, 208, 209, 210, 211, 212, 213, 217
  - Friction 211, 225
  - Hub 223
  - Key 224
  - Material 218–225
  - Pitch 206
  - Position 212
  - Protection from torpedoes 131
  - Slip 206
  - 2-bladed 210
  - 3-bladed 210
  - 4-bladed 210, 212
  - Bevis's feathering 202
  - Dundonald's 199, 201
  - Griffith's 200, 210
  - Hirsch's 200
  - Mangin's 201
  - Rankine and Napier's 201
  - Riggs's 201
  - Ruthven's 234
  - Thornycroft's guide-blade 203
  - Thornycroft's torpedo-boat 201, 216
- Propellers, Marine, Barnaby 200, 212, 224
- Propelling area 206
- Propulsion 199
  - Explosive 243
  - Hydraulic 234
- Propulsive efficiency 210
- Propulsive effort 199, 209
- Protection of:
  - Buoyancy and stability in ships 120
  - Commanding officers from fire 132
  - Crews from fire 60
  - Water-line of armored ships, table of 107
- Protective deck plate, (*see* Plates, protective deck).
- *Psyche*, cruiser, England 335
- *Pueblo*, S. S., manœuvring power of 457
- *Puritan*, coast-defense vessel, United States 332
  - Battery for 332
  - Electric installation of 246
  - Price of armor for 315

Q.

- Quick-fire guns (*see also* Rapid Fire Guns) 101, 102
- Quarters and offices, lighting of, at naval shore stations 285
- *Queen of the Pacific*, S. S., manœuvring power of 462
- Quintard Iron Works 322

Page.

R.

Raccoon, cruiser, England 338
Racing of screw propeller 217
Ram, tactics of the 173, 179–182
Range:
  Approximation to, progressive 171
  Approximation to, successive 171
  Dangerous, of modern guns 173
  Opening, of modern guns 173
Rankine and Napier's screw 201
Rapid-fire guns (*see also* Quick-fire guns) 149, 397–402
Rapidity of fire of R. F. guns, 4.72-inch 397
Ratio, disability 210
Ratio of pitch to diameter 230
Ratio, slip 208, 209
Rattlesnake, torpedo vessel, England, manganese-bronze, screws of 222
Raworth engine 275
Rayo, torpedo-boat, Spain 447-451
Redbreast, gun vessel, England 336
Redoutable, battle ship, France, (Plate II) 81
Reducing valve 251
Redoubts, separate, for heavy guns as compared with single citadel 104, 105, 106
Reduction in price of Government steel 296, 308
Regulations:
  Admiralty, concerning use of forced draft 366
  Queen's, concerning use of forced draft. 366
Regulator boxes 250
Remarks by Naval Inspector of Electric Lighting 288
Renown, battle ship, England 334
Replacement, wave of 213, 214
Report of U. S. Naval Advisory Board on mild steel 294
Repulse, battle ship, England 334
Requirements, test, for steel for U. S. vessels 294, 295, 296, 300, 302, 303, 304, 305, 306
Research, surveying vessel, England 340
Reserve, classification of ships in:
  England 5
  France 8
  Germany 12
  Italy 18
  Suggested scheme for the United States. 20
Resistance:
  Augmented 213
  Coefficient of frictional 211
Resistance experiments 88, 92, 106, 119, 418, 419
Resources of the United States, development of, for the production of war material 293
Results of insulation tests of electric light conductors 266–268
Retamosa, torpedo-boat, Spain 447–452
  Accident to screw of 447
  Torpedo practice of 448
Re Umberto, battle ship, Italy, (Plate III). 81, 84
Rhaetia, S. S., manœuvring powers of 463
Rhenish-Westphalian Powder Company 156, 319
Richmond Hill, S. S., manœuvring experiments with 459, 463

Page.

Rifles, magazine:
  Kropatschek 411
  Lebel 407
  Mannlicher 403–405
  New English 405
  Remington 412
  Vetterli-Vitali 410
Rigel, torpedo-boat, Spain 450
Rinda, cruiser, Russia, manganese-bronze, screws of 222
Ringdove, gun-vessel, England 336
Rival, turbine ship 241
Rivets 303, 306, 308
  Prices paid for 308
  Sources of supply of 323
Roach, John, shipbuilding company 322
Roanoke, S. S., manœuvring powers of 462
Robilant, S. S., manœuvring powers of 460
Rodney, cruise of, against commerce, British manœuvres 51
Rolls, size of, for plates and shapes 299
Rottweil-Hamburg powder 155, 418
Rover, cruiser, England, manganese-bronze, screws of 222
  Breech-loading battery of 136
Royal Sovereign, armored vessel, England, (Plate I) 81, 334
Rudder, torpedo-boat, Thornycroft 439
Ruggiero di Lauria, battle ship, Italy, (Plate III) 81, 84, 348
Rules:
  For manœuvres, English, naval 23, 24
  For vessels put out of action in do 25
  Governing cruisers preying on commerce 25, 26
  Governing torpedo attacks, English manœuvres 26, 27
  Of gun fire 171
Running lights 257

S.

Salamander, torpedo vessel, England 336
Sandfly, torpedo vessel, England 340
  Cruise of, against commerce, British manœuvres 54
San Francisco, cruiser, United States 332
  Electric installation of 246
  Cast-steel stem and stern-post of 298
  Steel for shafting of 297
Sanspareil, battle ship, England 336
Santa Rosa, S. S., manœuvring experiments with 458, 463
Sautter, Lemonnier & Co.:
  Lighting plant 289
  Manufacturing establishment of 289, 292, 320
  Search lights 277, 320
Sawyer-Mann Consolidated Electric Company 262
Sborul, torpedo-boat, Roumania 446
Schichau torpedo-boats:
  Aquila, Italy 445
  Avvoltoio, Italy 445
  Falco, Italy 445
  Krähe, Austria 438

Page.

- Schichau torpedo-boats—Continued.
  - *Kukuk*, Austria, 438
  - *Nibbio*, Italy, 445
  - *Sparviero*, Italy, 445
  - *Staar*, Austria, 438
  - Twin screw, Russia, 447
  - Sixteen sea-going, Germany, 444
  - 109, 110, 111, 112, 113, Italy, 445
  - 127-foot type, Italy, 445
  - 127-foot type, Russia, 447
  - 152-foot type, Italy, 445
  - No. XXXIV, Austria, 438
  - Order from Turkey for, 452
- Schneider et Cie. (Le Creusot), torpedo-boats:
  - 35ᵐ, France, 441
  - Nos. 139, 140, 141, 444
- School-ship, Spain, 355
- Schwartzkopff torpedo:
  - Contract with Italy for, 429
  - Dimensions of, 429
- Scientific papers, Navy, 205
- Scottish Oriental S. S. Co., manganese-bronze screws of steamers of, 222
- Screw propeller: (See Propeller.)
  - Position of, 212
  - Shafts and bearings, 228
  - Single *vs.* multiple, 225, 226, 227
  - The, 199
- Screw propellers:
  - Multiple, 225
  - Overlapped, 229
  - Sextuple, 233
  - Triple, 229, 230, 231, 232
  - Twin, 225, 226, 227, 228, 229, 232
- *Seagull*, torpedo vessel, England, 336
- Search light, 275–277
  - Automatic, 277
  - In Spanish manœuvres, 277
  - Proposed abolition of, for torpedo-boats, Spain, 76
  - Sautter-Lemonnier, 277, 320
  - Torpedo-boats, Spain, 448
  - Working with compound dynamos, 275
- Secondary batteries, 318, 324
  - Ammunition for, 318, 325
  - Proposed distribution of, English battle ships, 87, 89
- Second-class torpedo-boats, Denmark, tubulous boilers of, 369
- *Secretär*, torpedo-boat, Austria, 438
- Selwyn, Admiral, suggested propeller device of, 204
- *Seneca*, S. S., manœuvring powers of, 457, 461
- *Serpent*, cruiser, England, 338
- *Severn*, cruise of, against commerce, British naval manœuvres, 51
- Sévran-Livry powder, 157
- Sextuple screws, 233
- Shaft, propeller, inclined, 214, 215, 216
- Shafting:
  - For recent United States vessels, 297
  - Production of, 296
  - Sources of supply of, 323
- Shafts, screw, 228

Page.

- Shafts, screw, supports, 228
- Shape of propeller blades, 210, 211
- Shapes:
  - Facilities for the manufacture of, increased, 299
  - Production of, 296, 299, 323
- *Sharpshooter*, torpedo vessel, England, 336
- Sheathing, brass for propeller blades, 219
- *Sheldrake*, torpedo vessel, England, 336
- Shells, high explosive:
  - Effect upon distribution of armor, 177
  - Graydon's dynamite, 159
  - Gun cotton, 160, 161, 421, 422
  - Lyddite, 161
  - Melinite, 160, 375, 419
  - Smolianinoff, 160, 419
  - Snyder, 160
- *Shiodo*, cruiser, Japan, 361
- Ship-lighting plants, 288
- Ship plates (*see* Plates, ship).
- Ships:
  - France, gunpowder, torpedo discharge from, 192
  - Proposed, building (*see* Vessels).
  - Rooms, system in the German Navy, 12
- Shop lighting at naval shore stations, 285
- Shore stations, lighting plant for, as designed for minimum consumption of water, 291, 292
- Shrapnel, English:
  - Cast-iron, 159
  - Steel, 159
  - Table of bursting charges for, 159
- *Sicilia*, battle ship, Italy, dimensions and speed of, 117
- Siemens's volt and ampère meters, 250
- Sights, gun:
  - Errors of, 165–167
  - Graduation of, 172
  - Grenfell, 383
  - Position of, 165, 166
  - Use of, 165, 166
- Signals and communications, British manœuvres, 59
- Signals, defects of system employed in British manœuvres, 59
- Signal stations, 59
- Simond's rolling-mill, 319
- Simpson, Rear-Admiral, U. S. N., president U. S. Naval Advisory Board, 309
- Sims-Edison torpedo, 435
- *Sineul*, torpedo-boat, Roumania, 446
- Singer, Nimmick & Co, 323
- *Sinope* class, Russian armored vessels, water-line protection of, 107
- *Sinope*, battle ship, Russia, gun mounts of, 150
- *Sir Garnet Wolseley*, S. S., manœuvring power of, 460
- Size of battle ships, 114, 123
- *Skipjack*, torpedo vessel, England, 336
- Sligo Rolling-Mills, 323
- Slip, propeller, 206, 208, 213, 215
- Slip angle, 208
- Slip angle of maximum efficiency, 208
- Slip ratio, 208, 209

Page.

- Small-arms 402–412
  - Comparative table of modern 403
  - Austria 403
  - Belgium 405
  - Denmark 405
  - England 405
  - France 407
  - Germany 410
  - Introductory remarks on 402
  - Italy 410
  - Kropatschek 411, 412
  - Lebel 407–410
  - Mannlicher 403–405, 410
  - New model, English 405
  - Portugal 411
  - Remington 412
  - Spain 412
  - Turkey 412
- *Smertch*, armored vessel, Russia, (Plate I) .. 81
- Smokeless powder 155
- Smolianinoff shell 160
- Snyder shell 160
- Soho Iron Mills 323
- Solid Steel Casting Company 324
- *Soloven*, torpedo-boat, Denmark, tubulous boilers of 369, 439
- South Boston Iron Works 313, 324, 376
  - Contract with 376
- Spang Steel and Iron Company 323
- *Spanker*, torpedo vessel, England 336
- *Sparviero*, torpedo-boat, Italy 445
- Speed of new battle ships, England, discussion of 94, 96, 110, 111, 112
- Speed of ship's wake 212, 213
- *Speedwell*, torpedo vessel, England 336
- Specialty Steel Works 225
- Specifications:
  - Extracts from, in relation to quality of steel 300–305
  - For electric engines on board ships 246
  - For Army gun forgings 376–380
- *Sperber*, cruiser, Germany 354
- *Spider*, torpedo vessel, England 340
  - Cruise of, against commerce, English manœuvres 340
- Squadrons, English, losses of, under rules of manœuvres 57
- *Staar*, torpedo vessel, Austria 438
- Stabilimento Tecnico torpedo-boats:
  - *Flamingo* 438
  - *Gaulker* 438
  - *Harpie* 438
  - *Marabu* 438
  - *Secretär* 438
  - *Weihe* 438
- Staff, boiler room 365
  - engine room 365
  - General Naval (*see* General Naval Staff).
- *Stamford*, S. S., manœuvring power of 461
- *State of California*, S. S., manœuvring power of 462
- *State of Nebraska*, S. S., manœuvring power of 461
- Steam-engine *vs.* electric motors 280, 281

Page.

- Steam-gauge 250
- Steam Manual 366
- Steam piping 251
- Steam Reserve 5–8
- Steam trials, ships:
  - England 336
  - France 342
  - Germany 355
  - Italy 344
  - Russia 353
  - Spain 356
  - United States 332
- Steaming efficiency and endurance 60
- Steel:
  - Analyses of, by inspectors 306
  - Basic open hearth 306, 307
  - Bessemer 294, 307
  - Board, establishment of 296
  - Cost of 223, 296, 298, 308, 311, 314, 315, 316, 317
  - Clapp-Griffith 294, 306
  - Corrugated furnaces 296, 299
  - Crucible 294, 306
  - Forgings 294, 297, 305, 306, 308, 311, 312, 316, 317, 323, 324
  - Hammered, propeller blades 224
  - Improvement in quality of ...296, 300–307, 313, 314
  - Inspection by naval officers 295
  - Manufacture of, for Government, by private firms 293–299, 312, 313, 323, 324
  - Mild, for propellers 218, 219, 221
  - Plant, United States 294
  - Quality of, for naval guns 313, 314
  - Reduction in price of 296, 308, 311, 314
  - Shapes 294, 295, 296, 299, 302, 308, 323
  - Works, Specialty 225
- Stems:
  - Forged 298
  - Steel, weights of, United States vessels. 298
- Stern bracket 228, 232
- Stern posts:
  - Cast-steel, weights for United States vessels 298
  - Forged 298
- Stern tube 228
- Stiffening webs 228
- Stoke-holds:
  - Closed 366
  - Open 366
- Stokers, ships' 367
- Stokes' Bay, (screw trials in 225
- Storage batteries:
  - At shore stations 286
  - Of *Gymnote* 282
  - On shipboard 282
- *Storen*, torpedo-boat, Denmark 439
- Strategy in manœuvres 62
- Submarine boats:
  - France 453, 454
  - *Goubet* 454
  - *Gymnote* 453
  - *Peral* 438, 454
  - United States 453
- Suez Canal, risk of twin-screws in 219, 228
- Sulphur limit, Government steel 307

Page.

- *Sultan*, battle ship, England, screw trials 225, 227
- Supplies of war material, resources of United States 322–325
  - Ammunition 325
  - Castings, steel 324
  - Corrugated furnaces 324
  - Explosives 325
  - Forgings 323, 324
  - Machinery 322
  - Powder 325
  - Plates, armor 324
  - Plates, hull 323
  - Plates, protective and main deck 323
  - Projectiles 325
  - Rapid-fire guns 324
  - Torpedoes 325
- Supports, propeller shaft 228
- *Surcouf*, cruiser, manganese-bronze screws of 222
- Surface friction 209, 211, 212
  - Coefficient of 208, 209
- Swedish hydraulic torpedo-boat 234, 238
- *Swiftsure*, battle ship, England, screw trials of 225, 226
- Swinburne's converter 292
- Switch-board, electric 250, 255
- Switches and sockets, difficulties with 255
- Switches, one light 254

T.

- Tachometer 250, 290
- Tactics:
  - Gun 173–184
  - Gun (*Kearsarge-Alabama*) 163, 178, 179, 180
  - Of the ram 173, 179–182
  - Of the torpedo 173, 179, 181
- *Tage*, cruiser, France, manganese-bronze screws of 222
- *Takao*, cruiser, Japan 361
- *Tallahassee*, S. S., manœuvring power of 457, 460
- *Taormina*, S. S., manœuvring power of 460
- *Tchesma*, battle ship, Russia, gun mounts 150
- Telegraph cables, cutting in manœuvres 73
- *Téméraire*, torpedo-boat, France 189, 443
- *Téméraire*, battle ship, England, (Plate II). 81
- *Tempête*, armored vessel, France, (Plate II). 81
- Temporary circuits for lighting at naval shore stations 286
- Terre Noire projectiles 157
- *Terribile*, armored vessel, Italy 82
- *Terror*, coast defense vessel, U. S., electric installation of 246
- Testing set 250
- Test requirements:
  - Army gun forgings 376–380
  - For steel for United States vessels 300–306
- *Teutonic*, S. S., arrangement of screws of 229
- *Texas*, battle ship, United States 332
  - Armor for 311, 315
  - Price of steel for 308, 311, 315
- *The XII Apostles*, battle ship, Russia 353
- Thirty-five metre type torpedo-boats:
  - Building and built 441–443
  - Casualties 441

Page.

- Thirty-five metre type torpedo-boats—Cont'd.
  - Development of 441–442
  - History of 442
- Thomson-Houston Electric Company 320
- Thompson, Sir William, remarks on relative location of electric lighting plant and compasses 290
- Thornycroft, Messrs. J. I. & Co. 235, 236, 369–371
- Thornycroft torpedo-boats:
  - *Coureur* 444
  - *Havbestan* 439
  - *Narhvalen* 439
  - Propeller guard 439
  - Rudder 439
- Turbine boat 236
- Thornycroft water tubulous boilers 369–372
  - Efficiency of 371
- Thornycroft's guide-blade propeller 202, 203
- Thornycroft's hydraulic torpedo-boat 238, 242
- Thornycroft's torpedo-boat screw propeller 204, 216
- Thrust, propeller 214, 215
- Thurlow gun, trial of 393
- *Tonnerre*, battle ship, France, dynamo and engine, type and description of 289
- Torpedo-boat:
  - First class, speed of 216
  - Manœuvres, Spain 65, 447–451
  - *No. 100*, second class 369
  - Swedish 234, 238
  - Thornycroft's hydraulic 234, 238
- Torpedo-boats:
  - Armament of new 188, 189, 437
  - Austria 17, 18, 438
  - Denmark 439
  - Dimensions of new 437
  - Distribution of, in reserve 19
  - Equipment of 7, 13, 14, 16
  - England 7, 57
  - England, colonial 440
  - English, in naval manœuvres, table of. 29, 30
  - Exhaustion of crews of 58
  - France 64, 66, 189, 441
  - Germany 13, 16, 189, 444
  - Gunpowder discharge 189, 192, 194, 446
  - Holland 445
  - In British manœuvres 57
  - Inefficiency as protection of iron-clads 123, 124
  - Italy 19, 196, 445
  - Italy, stations 19
  - Liquid fuel for 440
  - New type of vedette boats recommended 58
  - Roumania 446
  - Russia 447
  - Spain 447
  - Spanish, details of 74, 447
  - Speed of new 437
  - Submarine 453–455
  - Surface 437–452
  - 34^m type (*see* Thirty-four metre torpedo-boats).
  - 35^m type (*see* Thirty-five metre torpedo-boats).
  - Thornycroft (*see* Thornycroft torpedo-boats).

Page.
Torpedo-boats—Continued.
  Turkey 452
  United States 189, 452
  Value of, to blockaded and blockaders 58
  Value of, Admiral Albini on 123
  Vedette 440
Torpedo booms, difficulty with 32, 36
Torpedo defense, Admiral Albini on 127
Torpedo discharge:
  Air and gunpowder 189–192, 196
  Comparison of, under water with above water 197
Torpedo, Howell, manufacture of 319, 325, 430
Torpedo howitzers, proposed breech-loading 382, 383
Torpedo motor, Edison's 283
Torpedo nets, difficulties in handling 32
Torpedo station, Newport, R. I 319, 325
Torpedo, tactics of the 173, 179, 181
Torpedo tubes, distribution of, in modern ships 185, 186, 187, 188
  Austria 186, 188
  England 186, 188
  France 186, 187, 188
  Germany 187, 188
  Italy 187, 188
  Russia 187, 188
Torpedo tubes, location of, on modern torpedo-boats 437
Torpedo-vessels, Chili 359
  England 335
  Germany 354
  Italy 343
Torpedoes, air-cartridge, for launching 190
  Automobile fish:
    Howell 189, 430
    Schwartzkopff 189, 428, 429
    Whitehead 189, 428, 429
  Controllable:
    Brennan 434
    Patrick 434
    Sims-Edison 435
  Drifting, Pietruski 436
  Fish, armament 185–198, 437, 438
    cartridge 190, 194
    ejection 189–196
  Gun 195
  Spanish exercises with, per cent. of hits 448, 449
  Value of, in evolutions 124, 125
  Whitehead, in English manœuvres 428, 429
Trabant, torpedo vessel, Austria 357
Trafalgar, battle ship, England, (Plate III), 81, 85, 88–91, 95, 99, 100–117; (Plate IV), 118
  Coal supply of 113
  Steam trial of 337
  Water-line protection of 107
Training squadron, modern guns for 376
Training of men should be more thorough in the ships in which they are to serve 11, 12, 32
Transactions of the Institution of Naval Architects 205
Trèhouart, coast-defense vessel, France 84, 341

Page.
Trenton, U. S. cruiser:
  First man-of-war lighted by electricity 261
  Installation of electric plant of 320
  Rewiring of 264
Trials:
  Armor 424–427
  Gun 386–393, 395
Trinidad, S. S., manœuvring power of 457, 461
Triple screws 229–232
Triplex dynamo 289
Tripoli, torpedo cruiser, Italy, triple screws of 232, 233
Triumph, battle ship, England, screw trials of 225, 226
Troude, cruiser, France, screw trials of 222
  Dynamo and engine, type and description of 289
Tube, stern, propeller 228
Tubes for guns, prices paid for 316, 317
Tubes, torpedo:
  Cail 193
  Canet 195
  Distribution of, on modern ships:
    Austria 186, 188
    England 186, 188
    France 186, 187, 188
    Germany 187, 188
    Italy 187, 188
    Russia 187
    Divergent 196
  Location of, on modern torpedo-boats:
    England 188, 189
    France 188, 189
    Germany 188, 189
    Italy 188, 189
  Schwartzkopff 189, 190
  Spoon:
    French 193
    German 194
  Under-water 197, 198
  Whitehead 192
Turbine, propeller 235, 236
Turret, Clark's deflecting 311
Turrets of *Miantonomoh* 311
Turrets *versus* barbettes 96
Twin screws 222, 225, 226, 227, 228, 229, 232
  Efficiency of 213
Two-wire system for lighting wires, as used in United States 291

U.

Umatilla, S. S., manœuvring powers of 462
Umberto I, battle ship, Italy 343
Umbria, cruiser, Italy 343
Underground circuits 285
Under-water torpedo tubes 197
Union Iron Works, Pittsburgh, Pa 323
Union Iron Works, San Francisco, Cal 322
Union Metallic Cartridge Company 325
United Service Institution 369
United States Electric Company 263
United States Electric Lighting Company 320
Urania, cruiser, Italy 343

Page.

Uses of electricity:
- At naval shore stations 270, 284
- On shipboard 270

V.

Valkyrien, cruiser, Denmark 359
Valve, reducing 251
Vanguard, battle ship, England, screw trials of 225, 226
Vautour, cruiser, France 342
Vavasseur central pivot carriage 152, 153
Vedette boats, new type of wooden 58
Venezia, armored vessel, Italy, (Plate I) 81
Ventilation of dynamo room 247
Vessels building, United States 332
Vessels launched:
- Austria 357
- Denmark 359
- England 335
- France 342
- Germany 354
- Greece 360
- Italy 343
- Japan 361
- Russia 353
- Spain 356
- United States 332

Vessels proposed or laid down:
- Austria 357
- Chili 358
- England 333
- France 341
- Germany 354
- Greece 360
- Holland 360
- Italy 343
- Japan 361
- Russia 352
- Spain 355
- United States 329

Vesuvius, cruiser, United States 332
- Additional cruiser of type of 331
- Electric installation of 246
- Steel shafting for 297

Veterli-Vitali magazine rifle, Italy 410
Vibration, due to propeller 218
Vice-Admiral Popoff, circular armor-clad, Russia 233
Vicker's steel for propellers 219
Vicker's steel armor-plate 425
Victoria, S. S., manganese-bronze screws of 220
Victoria, battle ship, England, (Plate III) 81
Villaverde, S. S., manœuvring power of 462
Viola, S. S., manœuvring power of 462
Viper, gun vessel, England 234
Virtual pitch angle 208
Vladimir Monomakh, armored cruiser, Russia (Plate III) 81
Volage, cruise of, against commerce, British manœuvres 54
Volt-meter 250, 290
Von Förster's fuze for gun-cotton 161, 420
Vulcan Iron Works 308

Page.

Vulcan, torpedo-transport ship, England 335
Vulcanite 225

W.

Wacht dispatch vessel, Germany 355
Wake, speed of ship's 212, 213
Walsrode, gun-cotton shell 161, 375, 420
War order, secret, given to officers, Austria 18
Warrior, armored vessel, England, (Plate I) 81, 82
- Dimension and speed of 117

"War ships of the future," by Admiral Albini 123
War studies:
- Division of, into semi-political and military 2
- Military, divisions of 2
- Necessity of 2, 3

Warspite, armored cruiser, England 51, 88
- Disposition of armament of 88

Washington navy-yard 309, 310, 318, 324, 325
- Manufacture of cast-iron projectiles at 318

Water-line protection of ships:
- Armor, tabulated 107
- Cellular 120–122

Water-tight receptacle, electric fittings 255
Watertown Arsenal 324
Watervliet Arsenal 309, 324
Waterwitch, hydraulic propulsion, England 234, 237, 238
Wattignies, cruiser, France 341
Wave of replacement 213, 214
Webb, stiffening for shaft 228
Weehawken and *Atlanta*, contest of 163
Weihe, torpedo-boat, Austria 438
Werra, S. S., manœuvring powers of 462
West Point Foundry 313, 324, 376
- Contracts with 376

Westernland, S. S., manœuvring powers of 461
Westmoreland, S. S., manœuvring powers of 458, 462
Wetteren powder 417
Weyl, E., Lieut., criticism of French scheme of mobilization 11
White, Mr. W. H.:
- On screw propulsion 213, 225, 228
- Paper of, on new battle ships, England 97

White Star Line, steamers, manganese-bronze screws of 221
Whitehead torpedo:
- Dimensions 189, 429
- Number manufactured in England 429
- Ships, torpedoed by, in British manœuvres 429

Whiting, torpedo vessel, England 335
Whitworth gun forgings 316, 317
Whitworth liquid compression plant at Bethlehem 312
Whitworth steel shafting 297
Willamette, S. S., manœuvring power of 461
Willamette Valley, S. S., manœuvring power of 461
Willans engine 273
William Cramp & Sons Ship-building Company 322

Page.

Winchester Arms Company 325, 375
Wire:
  Electric, lead covering recommended for 260, 261
  Molding 252, 253
  Stapling 252, 253
  Supplied to *Baltimore*, *Charleston*, *Pensacola*, and *Yorktown*.................. 265
Wire-wound guns:
  English, opinion of Court on 137
  Maitland, 9.2-inch....................138, 139
  Russian................................ 385
Wiring:
  Electric................................ 259
  Atlanta, cruiser, U. S 263, 268
  Baltimore, cruiser, U. S.................. 265
  Boston, cruiser, U. S...................263, 268
  Charleston, cruiser, U. S 265
  Chicago, cruiser, U. S..................263, 268
  Dolphin, despatch vessel, U. S......... 261
  New Hampshire, receiving ship, U. S... 262
  Omaha, cruiser, U. S...................262, 268
  Pensacola, cruiser, U. S 265
  Trenton, cruiser, U. S..........261, 264, 265, 268
  Yorktown, cruiser, U. S............265, 266, 268
  Interior Department.................... 266
  Fixtures 255, 256
  In general 246, 247, 250
Wizard, torpedo vessel, England............ 335

Page.

Wood armor 121, 122
Woodite for cellular water-line protection . 121
Wyoming, S. S., manœuvring power of....457, 462

Y.

Yaeyama, dispatch vessel, Japan 361
Yarrow torpedo-boats 437, 439, 447
  Empong, Holland 445
  No. 79, features of 439, 445
  Second class—
    England 440
    Russia 447
Yorkshire, S. S., manœuvring power of..... 461
Yorktown, cruiser, United States 333
  Completion of battery for................ 376
  Dynamos of...........................271, 272
  Electric installation of................246, 265
  Electric plant of 271
  Prices paid for steel for................ 308
  Specification for insulation of wire in.. 265
  Steel shafting for 297

Z.

Z-bar, 10-inch, rolled at Phœnix Works 299
Zealandia, S. S., manœuvring power of....457, 462
  Comparison of performance of, with bronze and steel screws.............221, 223
Zinc, protection of stern frames against galvanic action with.......................218, 225